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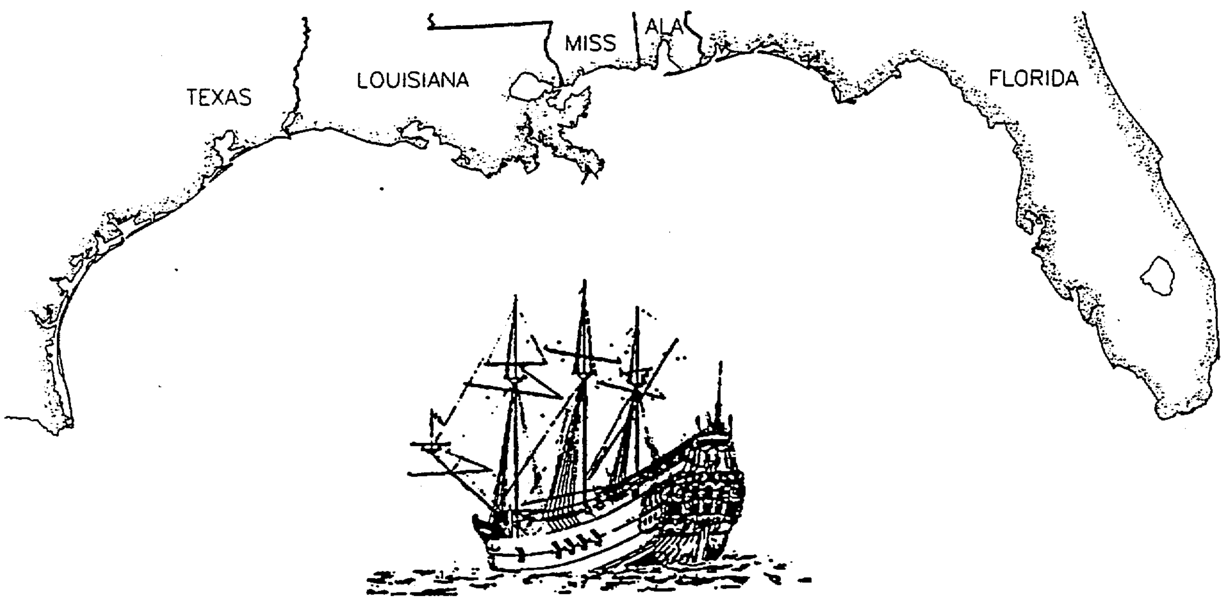
OCS Study
MMS 89-0025

Historic Shipwrecks and Magnetic Anomalies of the Northern Gulf of Mexico

Reevaluation of Archaeological Resource Management Zone 1

Volume III: Appendices



MMS
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Historic Shipwrecks and Magnetic Anomalies of the Northern Gulf of Mexico

Reevaluation of Archaeological Resource Management Zone 1

Volume Ill: Appendices

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Prepared under MMS Contract
14-12-0001-30330
by
The Texas A&M Research Foundation
Box 3578
College Station, Texas 77843

Published by

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Regional Office

New Orleans
September 1989

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CITATION

Suggested citation:

Garrison, E. G., C.P. Giammona, F.J. Kelly, A.R. Tripp, and G.A. Wolff. Historic Shipwrecks and Magnetic Anomalies of the *Northern* Gulf of Mexico: reevaluation of *archaeological* resource management zone 7. Volume I Ii: Appendices. OCS Study/MMS 89025. U.S. Dept of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, La. 248 pp.

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APPENDIX A

Vessels Attacked in World War II in Gulf Area

and

German U-Boat Casualties in World War II

Table A-1.

VESSELS AITACKED IN WORLD WAR II IN GULF OF MEXICO, STRAITS OF FLORIDA, AND SOUTH ATLANTIC OFF FLORIDA TO 78° W.

Date	Latitude N.	Longitude W.	Vessel Type	Tonnage	Name	U-Boat
5/3/42	26°04’,	79°45’	Steamship	567	Sama	U-506
514/42	24°57’	84°00’	Steamship	2,686	Norundo	U-507
5/5/42	25°24’	83°46’	Tanker	5,104	Munger T. Ball	U-507
5/5/42	25°57’	83°57’	Tanker	6,950	Joseph M. Cudahy	U-507
5/6/42	28°35’	88°22’	Steamship	6,759	Alcoa Puritan	U-507
5/8/42	28°11’	87°32’	Steamship	3,099	Ontario	U-507
5/8/42	26°40’	86°40’	Steamship	2,424	Torny	U-507
5/10/42	28°35’	90°00’	Tanker (D)	7,050	Aurora (towed to port)	U-506
5/12/42	28°53’	89”29’	Tanker	10,731	Virginia	U-507
5/13/42	28°29’	89°17’	Tanker	8,862	Gulf Penn	U-506
5/14/42	28°30’	89°55’	Tanker	6,821	David McKelvy	U-506
5/16/42	26°30’	89°12’	Steamship	4,148	Ampala	U-507
5/16/42	28°52’	90°20’	Tanker (D)	7,302	William C. McTarnahan	U-506
5/16/42	28°41’	90°19’	Tanker (D)	9,002	Sun	U-506
5/17/42	28°08’	89°46’	Tanker	5,189	Gulf Oil	U-506
5/19/42	28°53’	91°03’	Steamship	4,732	Heredia	U-506
5/19/42	23°30’	86°378	Steamship	5,037	Ogontz	U-103
5/20/42	28°42’	90°08’	Tanker	6,986	Halo	U-506
5/20142	22°55’	84°26’	Steamship	7,191	George Calvert	u-753
5/20142	24°30’	83°55’	Sailing Ship (D)	326	E.P. Theriault	u-753
5121142	23°30’	84°24’	Tanker	6,067	Fasa de Oro	U-106
5/25142	28°45’	90°03’	Tanker(D)	6,582	Haakon Havan	u-753
5/26/42	26°18’	89°21’	Tanker	5,030	Carrabulle	U-106
5/27/42	25°50’	89°05’	Steamship (D)	4,639	Atenas	U-106
5/28/42	24°11’	87°02’	Steamship	7,383	Mento	U-106
6/1/42	22°45’	85°13’	Steamship	2,689	Hampton Roads	U-106
6/7/42	23°08’	84°42’	Steamship	5,234	Hermis	U-158
6/11/42	28°41’	91°20’	Tanker	13,467	Sheherzade	U-158
6/12/42	29°02’	91°59’	Tanker	8,192	Cities Service Toledo	U-158
6/16/42	24°05’	81°40’	Steamship	2,220	Managua	U-67

Table A-1
(continued)

6/1 7/42	25”26’	95°33’	Steamship	3,601	San Bias	U-158
6117142	25°35’	96°20’	Tanker	1,560	Moira	U-158
6/18/42	23°12’	79°28’	Steamship	3,274	Millinocket	U-129
6120142	28°41’	89°34’	Tanker (D)	8,221	Nortind	U-67
6123142	28°53’	89°15’	Tanker	3,664	Rawleigh Warner	U-67
6/27142	20”15’	96°20’	Tanker	7,008	Tuxpam	U-129
6/27/42	20°15’	96°20’	Tanker	2,005	Las Chaoapas	U-129
6/29/42	29°25’	85°17’	Tanker	8,032	Empire Mica	U-67
7/1/42	22°50’	92°30’	Steamship	1,855	Cadmus	U-129
712/42	23°33’	92°35’	Motorship	1,841	Gunderson	U-129
714142	22°13’	86°06’	Tanker	6,320	Tuapse	U-129
7/6/42	29°35’	88°44’	Motorship	2,160	Bayard	U-67
7/7/42	25°35’	80°02’	Steamship	8,141	Unitata	U-571
7/7/42	29°26’	88°38’	Tanker (D)	6,610	Paul H. Harwood	U-67
7/9/42	23°54’	82°33’	Steamship	1,051	Nicholas Cuned	U-571
7/10/42	20°05’	90°05’	Tanker	5,950	Benjamin Brewster	U-67
7/13/42	23°32’	81°02’	Steamship	5,990	Andrew Jackson	U-84
7173142	28°50’	91°05’	Tanker	7,989	R.W. Gallagher	U-67
7/15/42	24°05’	83”42’	Tanker (D)	11,394	Pennsylvania Sun	U-571
7/16/42	23°32’	82°00’	Steam Trawler	16	Gertrude	U-166
7119/42	25°14’	82°27’	Steamship	1,648	Basa California	U-84
7/19/42	23°39’	84°00’	Steamship	1,266	Port Antonio	U-129
7121142	24°08’	82°23’	Steamship	7,176	Wiliam Cullen Bryant	U-84
7123142	22°40’	78°44’	Steamship	2,310	Onondaga	U-129
7126/42	28°23’	96°08’	Steamship	4,351	Oaxaca	U-171
7130142	28°40’	88°42’	Steamship	5,184	Robert E. Lee	U-166
8112/42	24°20’	81°50’	Steamship	1,685	Santiago de Cuba	U-508
8112142	24°20’	81°50’	Steamship	1,025	Manzanillo	U-508
8/13/42	28°50’	90°42’	Tanker	6,779	R. M. Parker, Jr.	U-171
9/4/42	23°27’	97°30’	Tanker	6,511	Amatlan	U-171
4/2/43	23°09’	83°24’	Steamship	1,091	Lysefjord	U-155
4/3/43	24°26’	80°18’	Tanker	6,882	Gulfstate	U-155

Table A-2.

GERMAN U-BOAT CASUALTIES IN WORLD WAR II.

	Latitude N.	Longitude W.	U-Boat
6/7/42	24°13'	82°03'	U-157
8/1/42	28°37'	90°45'	U-166
5/15/43	23°21'	80°18'	U-176
	24"52'	83°19'	U-2513

Source: United States Submarine Losses - World War II
Naval Historical Division
Office of the Chief of Naval Operations
Washington, D.C. 1963

APPENDIX B

Historic Maps, Charts and Sailing Directions

Table B-1.

LIST OF HISTORIC MAPS, CHARTS, SAILING DIRECTIONS AND MISCELLANEOUS CHARTS.

Historic Maps and Charts

1519 -	"Mapa de la Costa Firme descubiertas por Juan Ponce, Francisco de Garay, Diego Velasquez. etc." 1st map of Gulf
1524 -	"Map of Mexico City and the Gulf Coast." Hernan Cortés (Schwartz and Ehrenberg 1980; Weddle 1985). 2nd map of Gulf, 1st published.
1569 -	"Nova et aveta orbis terrae description ad vsvm navigantium emendate accommodate." Gerard Mercator. Isogonic cylindrical projection presented for the most the first time. One of the most influential maps ever published (Schwartz and Ehrenberg 1980).
1572 -	"Mapa del Golfo y Costa de Nueva España desde el Rio de Panuco hasta el Cabo de Santa Elena, etc." alonso de Santa Cruz. (Schwartz and Ehrenberg 1980; Martin and Martin 1982). cf. landmarks.
1647 -	"America carta particular dells Baia de Messico con la costs." Sir Robert Dudley (Martin and Martin 1980). Shown are winds and currents - poor representation of Mississippi River delta.
1692 -	"Map of America" Rouillard (Weddle 1985; Le Clerq 1691).
1715 -	"Les Costes aux Environs de la Riviere de Mississippi." Nicolas de Fer (Martin and Martin 1980).
1715 -	"A Map of the West Indies." Herman Mon. Historic Urban Plans. Ithaca, N.Y. Tracks of galleons.
1722 -	"Carte du Mexique et de la Florida." Guillaume De 1' Isle. Reproduced from original at P.K. Younge Library. University of Florida, Gainesville. Route of Flotas.
1744 -	"Carte De La Louisiana." Nicolas Benin. (O'Neill 1977),
1744 -	"Partie De La Coste De La Louisiane et De La Floride." Nicolas Benin (O'Neill 1977).
1763 -	"Plan of the Bay of St. Joseph in the Gulf of Mexico." Thomas Jeffreys. Facsimile reproduction 1976.
1763 -	"A Plan of Bahia Del Espiritu Santo and the West Side of Florida." Thomas Jeffreys. Facsimile reproduction 1976.
1763 -	"Plan of the Bay and Island of Mobile." Thomas Jeffreys. Facsimile reproduction 1976.
1763 -	"Florida," Thomas Jeffreys. Facsimile production 1976.
1775 -	"Map of Part of East Florida." Bernard Remans. Reproduction, facsimile 1962, Gainesville.
1775 -	"The Western Coast of Louisiana and the Coast of New Leon." Thomas Jeffreys (Martin and Martin 1980). 1st representation of Continental Shelf; Track of Flotas.
1777 -	"Insule Americana." Reiner and Josua Ottens. Reproduced from original copy in P.K. Younge Library. University of Florida. Gainesville.
1803 -	"The Coast of the Gulf of Mexico." George Gould. Copy of original in Library of Congress.
1816 -	"Map of the United States." John Melish. (Martin and Martin 1982)
1820 -	"A Map of Mobile in the State of Alabama." Curtis Lewis. (Guthorn 1984).
1833 -	"A New Chart of the Tortugas Keys and Shoals." Samual M. Stuart (publisher) (Guthorn 1984).

Table B-1
(continued).

1833 - "A New Chart of Key West, with the North-West Passage." Samual M. Stuart (publisher) (Guthorn 1984).
1834 - "The Coasts of West Florida, Alabama, Mississippi, and Louisiana. Edmund Blunt. (Guthorn 1984).
1840 - "Chart of Mobile Bay." Curtis Lewis and captain Welsh (Guthorn 1984).
1847 - "Sketch of the results from soundings at the entrance to Mobile Bay." C.P. Patterson (Guthorn 1984).
1851 - "Rebecca Shoal, Florida Keys." F.H. Gerdes. (Guthorn 1984).
1851 - "Preliminary Sketch of Mobile Bay." F.H. Gerdes *et al* (Guthorn 1984).
1851 - "Grand Bay Including the Entrance of Horn Island Pass." W.E. Green well. (Guthorn 1984).
1853 - "Horn Island Pass, Mississippi Sound." F.H. Gerdes (Guthorn 1984).
1853 - "Preliminary Reconnaissance of the Entrance to Barataria Bay, Louisiana." F.H. Gerdes. (Guthorn 1984).
1853 - "Reconnaissance of Sabine Pass, Texas." J. Wilkinson (Guthorn 1984).
1853 - "Galveston Entrance, Texas." R.H. Fauntleroy (Guthorn 1984).
1853 - "Preliminary Chart of San Luis Pass." A.D. Bathe (Guthorn 1984).
1853 - "Reconnaissance of Aransas Pass, Texas." H.S. Stellwagen (Guthorn 1984).
1855 - "Tampa Bay, Florida." O.H. Berryman. (Guthorn 1984).
1860 - St. George's Sound, Florida." A.D. Bathe. (Guthorn 1984).
1865 - "Wall Atlas." Arnold Guyot (Schwartz and Ehrenberg 1980).

Sailing **Directions**

1564 - Testimony from a meeting of the officials of the House of Trade, the Prior and consuls, and masters and pilots. Francisco Rodr íguez (Notary January 18 (Sevilla, Archives General de las Indies) (AGI), Indiferente General 2005; McDonald and Arnold 1979.
1564 - Opinion of the masters, pilots, and shipowners. Benito Luis (Notary). Seville, February 9 (Sevilla, AGI, Indiferente 2005; McDonald and Arnold 1979).
1583 - Sailing Directions for the Coasts of Mexico (London, British Museum, MSS.28, 189; McDonald and Arnold 1979).
1712 - Ship course from San Lucas, Spain, to San Juan de Ulua and back to Spain, by Juan Antonio de Orbe, November (Sevilla, AGI, Contraction 4890; McDonald and Arnold 1979).
1717 - Directions by the company of the west for inward and outward voyages. Archives Nationals, Colonies, Paris, Série C^{13}, Correspondence Generale, Louisiane, 1679-1763 (A. N., C., Ser C^{13})) vol. v, fols. 16, -36-41; A. N., C., Ser, B, vol. lxxxvii, fol 8. (Surrey 1916).
1775 - Directions for Coming round Cape St. Antonio, through the Gulf of Florida. B. Remans.
1775 - General Directions for the Dry Tortugas and the Florida Reef and Keys with their description. George Gauld.
1820 - "Description de la Costa Septentrional y Oriental de Seño Mexicano desde La Bahia de San Bernardo hasta Las Tortugas." Derrotero de Las Antillas, De Las Costas De Tierra Firme, Y De Las Del Seño Mejicano. Seville.

Table B-1
(continued).

1833 -	Directions. A New Chart of the Tortugas Keys and Shoals (Guthorn 1984).
1833 -	Directions. A New Chart of Key West, with the Northwest Passage (Guthorn 1984).
1839 -	"No sure Sailing Directions..." Reconnaissance of the N.E. and S.E. Passes and Passe A L'Outre (Guthorn 1984).
1847 -	Sailing Directions. Sketch of a Reconnaissance of the Harbor South of Cat Island on the Coast of Mississippi (Guthorn 1984).
1850 -	Sailing Directions, Cat and Ship Island Harbor. (Guthorn 1 984).
1851 -	Sailing Directions. Preliminary Chart of Key West Harbor and Approaches (Guthorn 1984).
1851 -	Sailing Directions. Preliminary Sketch of Mobile Bay, Alabama (Guthorn 1984).
1852 -	Sailing Directions. Reconnaissance of Channel No. IV. Cedar Keys, Florida (Guthorn 1984).
1852 -	Sailing Directions. Reconnaissance of the Passes of the Delta of the Mississippi, Louisiana showing the changes since 1839 (Guthorn 1984).
1853 -	Sailing Directions. Galveston Entrance, Texas. (Guthorn 1984: 181).
1853 -	Sailing Directions. Preliminary Chart of San Luis Pass, Texas (Guthorn 1984).
1853 -	Sailing Directions. Preliminary Reconnaissance of the Middle or Main, and West Entrances to St. Georges' Sound, Florida (Guthorn 1984).
1853 -	Sailing Directions. Reconnaissance of Aransas Pass, Texas (Guthorn 1984).
1853 -	Sailing Directions. Horn Island Pass, Mississippi Sound (Guthorn 1984).

Miscellaneous Charts

1985 -	"Shipping Routes to Points outside the Gulf." Gulf of Mexico. Coastal and Ocean Zones Strategic Assessment Data Atlas, National Oceanic and Atmospheric Administration (NOAA).
1985 -	"Shipping Routes within the Gulf." (ibid)
1985 -	"Bathymetry." (ibid)
1985 -	"Bottom Sediments." (ibid)
1985 -	"Remotely Sensed Sea Surface Temperature." (ibid)
1985 -	**"OCS Oil** and Gas Activities." (ibid)
1985 -	"Oil Production." (ibid)

APPENDIX C

Summary Statistics of Blockade Runners
(after Price 1973)

Table C-1.

SUMMARY STATISTICS OF BLOCKADE RUNNERS' SUCCESS AGAINST THE BLOCKADE IN GULF OF MEXICO (after Price 1973).

Summary for 1861:					
Vessels engaged in the business:	steamers	34	others, including unascertained types,	397	total 431
Number of runs attempted:	steamers	375	others, including unascertained types,	1348	total 1723
Successful runs:	steamers	371	others, including unascertained types,	1293	total 1664
Unsuccessful runs:	steamers	4	others, including unascertained types,	53	total 57
0/0 of successful runs:	steamers	99%	others, including unascertained types,	96%	all types 970/.
Summary for 1862:					
Vessels engaged in the business:	steamers	34	others, including unascertained types,	222	total 256
Number of runs attemped:	steamers	68	others, including unascertained types,	360	total 428
Successful runs:	steamers	50	others, including unascertained types,	229	total 279
Unsuccessful runs:	steamers	18	others, including unascertained types,	131	total 149
% of successful runs:	steamers	73%	others, including unascertained types,	630/.	all types 65%
Summary for 1863:					
Vessels engaged in the business:	steamers	38	others, including unascertained types,	216	total 254
Number 01 runs attempted:	steamers	99	others, including unascertained types,	329	total 428
Successful runs:	steamers	73	others, including unascertained types,	193	total 266
Unsuccessful runs:	steamers	26	others, including unascertained types,	136	total 162
°/₀ of successful runs:	steamers	74%	others, including unascertained types,	58%	all types 62%
Summary for 1864:					
Vessels engaged in the business:	steamers	25	sailing vessels,	119	total 144
Number of runs attempted:	sfeamers	100	sailing vessels,	173	total 273
Successful runs:	steamers	87	sailing vessels,	91	total 178
Unsuccessful runs:	steamers	13	sailing vessels,	82	total 95
°/₀ of successful runs:	steamers	870/.	sailing vessels,	53%	all types 65%
Summary for 1865:					
Vessels engaged in the business:	steamers	25	sailing vessels,	33	total 58
Number 01 runs attempted:	steamers	69	sailing vessels,	39	total 108
Successful runs:	steamers	65	sailing vessels,	11	total 76
Unsuccessful runs:	sleamers	4	sailing vessels,	28	total 32
°/₀ of successful runs:	steamers	94°/0	sailing vessels,	53 %	all types 65"/₀

Table C-1
(continued).

Overall Summary, 1861-1865:

Vessels engaged in the business:	steamers	156 others, including unascertained types,	987	total 1143
Number of runs attempted:	steamers	711 others, including unascertained types,	2249	total 2960
Successful runs:	steamers	646 others, including unascertained types,	1817	total 2463
Unsuccessful runs:	steamers	65 others, including unascertained types,	430	total 495
% of successful runs:	steamers	9 1%, others, including unascertained types,	81%	all types 83%

APPENDIX D

Gulf Blockade Runners Sunk or Destroyed by Year, 1861-1865
(after Price 1973)

Table D-1.

GULF BLOCKADE RUNNERS SUNK OR DESTROYED BY YEAR, 1861-65
(AFTER PRICE 1973).

1861

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
Ann Ryan	schooner			burned off Galveston, 4 July	for	1
Finland	ship			burned Appalachicola Bay, 26 Aug.		
Falcon	schooner			wrecked off Galveston, 5 July	for	
Reindeer	schooner			scuttled off Lamar, Texas 3 Oct.	for	
Tom Hicks	schooner			sunk off Galveston, 9 July		
TOTAL 1861 = 5						

1862

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
A.B.	steamer			run aground and burned by Confederates off Nueces River, 15 Aug.	for	
Andreila (J.W. Wilder)	schooner			grounded and abandoned by crew off Fort Morgan (Mobile), 20 Jan.		
Anna Smith	schooner	19937/95		destroyed Cedar Keys, 10 Jan.		
Antonica	schooner			grounded off Fort Morgan (Mobile) and burned by Confederates		
Baker	schooner			wrecked off Mobile, Dec	for	
Black Joker (C. Vanderbilt)	steamer	383		foundered at sea, March	for	2
Caroline	sloop			sunk off west coast of Florida, March		2
Columbia	schooner		7	captured and burned San Luis Pass, 5 Apr.	from	2

Table D-1
(continued),

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
Conchita	schooner			burned off Texas coast, Oct.		
Cygnet	schooner (pilot boat)			burned off Appalachicola, 2 April		
Dudley (Pinkney)	sloop			destroyed off Cedar Keys, 10 Jan.		
Deer Island	schooner	3766,95	3	scuttled by crew, Mississippi Sound, 13 May	from	
Julia	schooner			destroyed off New Orleans, 24 Jan.	from	
J.W. Townsend	schooner			grounded near Pensacola and burned by crew, during or about April		
Mary Olivia	unascertained (pilot boat)			burned Appalachicola, 2 Apr.		
Monte Christo	sloop			burned by Confederates off coast of Texas, 10 July		
Mustang	sloop			abandoned coast of Texas, Feb.		
Ocilla	schooner			destroyed Cedar Keys, 10 Jan		
O.K.	sloop			sunk Cedar Keys, Feb.		
Pioneer	sloop	12 22/95	4	destroyed off Rio Grande, 20 Feb.	for	
Ranger	steamer (river boat)			wrecked and lost 120 miles south of Matamoras, Aug.		
Rattler	sloop			destroyed Cedar Keys, 10 Jan.		
R. Burrows (Rhode Borroughs)	sloop	60		beached and burned off Mobile, Oct.		

Table D-1
(continued).

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
Spitfire	schooner			sunk west coast of Florida, Mar.		
Stag	schooner			destroyed Cedar Keys, 10 Jan.		
Swan	sloop			abandoned coast of Texas, Feb.		
Tardy	schooner			ran agound after leaving Mobile, burned by master, Feb.		
Wave	sloop			captured and destroyed by U.S. in Mississippi Sound, 27 June		
William H. Middleton	sloop			destroyed Cedar Keys, 10 Jan.		
Wyfe	schooner			destroyed Cedar Keys, 10 Jan.		
TOTAL 1862: 31						
1863						
Caroline	schooner			destroyed Ocklockonee River, Fla., 28 Dec.		
Caroline Gertrude	schooner			grounded on bar off Ocklockonee River, set afire by US. Navy		
Concordia	schooner			destroyed Calcasieu Pass, 5 Oct.		
Cuba	steamer			fired by crew, abandoned and sunk lat. 28° 47'N, long. 87° 58'W., 17 May	for	
Director	schooner	2.30	2	captured and destroyed at Punta Rasa, 30 Sept.	for	
Fanny (Fox)	steamer	381		burned by master near Pascagoula, Miss., to prevent capture, 12 Sept.		

Table D-1
(continued).

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
Florrie	schooner			captured 6 miles off Matagorda and burned, 2 Oct.	for	
Isabel	schooner	91		burned off Mobile, 18 May	from	
Jane	schooner			destroyed off Rio Brazes, 10 Oct.		
Mary Jane	schooner			while being chased, ran aground on small key near Clear-water, and destroyed, 18 June	for	
Matamoras	schooner			wrecked in Matagorda Bay		
Matilda	schooner			wrecked in Matagorda Bay		
Powerful	steamer			destroyed in Suwanee River, 20 Dec.		
Prima Donna	schooner			wrecked 10 miles east of Mobile Point, 30 March	for	1
Relief	schooner	29 18/95		wrecked at Sand Island, off Mobile, in Mar., or Apr.	for	2
Victoria	sloop			burned off Texas coast, 30 May		
TOTAL 1863: 16						
1864						
Caroline (Rosita, Union)	steamer	164 74/195		burned off Galveston, 7 July	from	1

Table D-1
(continued),

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
Cassie Holt	sloop			destroyed San Luis Pass, 29 Feb.	from	
Clifton	schooner			grounded on bar off Sabine Pass, burned by own crew, 21 Mar.	from	
Etta	schooner			destroyed near Cedar Keys, Fla., about 30 Mar.		
Good Hope	schooner	150		beached by own crew and burned by U.S. Navy, lat. 28° 34'N., long. 83° 10' W., 18 Apr.	for	
Ivanhoe	steamer			chased ashore and destroyed off Mobile, 4 July	for	2
Little Lilly	steamer	230 04/95		destroyed Suwanee River, 2 Feb.	from	3
Marion	schooner			captured off Rio Brazes, 12 Mar., Unsea-worthy ;sunk by U.S. Navy		
Mary Ann	sloop			destroyed off Pass Cavallo, 8 Dec.	from	
Matagorda	steamer			destroyed off coast of Texas, 8 July		
Rosina	sloop			chased ashore and burned San Luis Pass, 13 Apr.	for	
Wild Pigeon	schooner	37		run down and sunk off Florida coast, 21 Mar.	for	

TOTAL 1864: 12

Table D-1
(continued).

Name of vessel	Type	Tons	Crew	Location	Bound	Runs
1865						
Annie	sloop		2	captured off Crystal River Fla., 11 Apr. Destroyed after cargo removed	from	
Denbigh	steamer	162		ran aground off Galveston, shelled, boarded, and burned, 24 May	from	7
Florida	sloop			captured off Crystal River, Fla., 11 Apr. Destroyed after cargo removed	from	
Louisa	schooner			chased ashore at Aransas Pass and sunk by shell fire, 16 Feb.		
Mary Agnes	schooner			destroyed at Aransas Pass, 16 Feb.	for	
Rob Roy	schooner	60		run ashore and burned Steinhatchie River, 2 Mar.		
Will O' the Wisp	steamer			destroyed off Galveston, 9 Feb.	for	1

TOTAL 1865: 7

TOTAL 1861-1865: 71

APPENDIX E

Common Historic Vessel Types of the Northern Gulf of Mexico: Brief Descriptions

Table E-1.

COMMON HISTORIC VESSEL TYPES OF THE NORTHERN GULF OF MEXICO: BRIEF DESCRIPTIONS.

Vessel Illustrations from Chapelle 1951; Chapman 1968; Fleetwood 1982; Paasch 1890.

Sixteenth & Seventeenth Centuries

1. Bark. Barque. Two-three masts; square rigged on main only, fore-and-aft on others (Wilson 1983; Villiers 1973). Prevalent after 1585 (Chaunu and Chaunu 1955, Vol 6 (2)).
2. Bateau. French for "boat". Could have mast with square reg. Surrey (191 6) reports bateaux up to 40 tons.
3. Bilander. Two masts; similiar to brig in terms of rig (see McWilliams, 1981).
4. Biscayan. Double-ended longboat. Masts probably not stepped e.g. folding or detachable (McWilliams 1981).
5. Brigantine. Generic term in records (Surrey 1916). Size varies from boat to ship with rig of two masts (Wilson, 1983).
6. Caiche. Probably a ketch. Surrey (1916) says few were ever used in Louisiana. Chapelle (1976) sees the ketch evolving into schooners by the early 1700's implying fore-and-aft rigs.
7. Canoe. Surrey (1916) discusses these water craft at length. "Master canoes" could reach lengths of 42 feet (ibid). Typically bark-covered but some were of hide.
8. Caravel. Also "caravelle". Square-rigged on fore and main, lateen on mizzen. Small in size - 10-50 tons. Used by Spanish from 1500 through 1650 being replaced by "navies" (ships) and larger galleons (Chaunu and Chaunu 1955; Wilford 1985).
9. Chaloupe. Shallop. Double-ended boat with masts (2). Chapelle (1951) defines it as open, 18-28 feet with no decks.
10. Corvette. Two-three masts, square rigged. Warship smaller than a frigate with 10-20 guns (Millar 1978). Corvettes of later centuries were characterized by flush decks (Howard 1979).
11. Felucca. felouque. Lateen-rigged, double-ended vessel. Small -25 to 28 feet in written sources (Millar 1978 and Chapelle 1951). Powered by oars and sails (Surrey 1916).
12. Flyboat. filibote. Also called "fluyt". Ship-rigged on fore and main masts, lateen on mizzen (Villiers 1973). Stern castles present. Used regularly in Spanish trade 1580-1640 (Chaunu and Chaunu 1955).
13. Frigate. Keel:beam ratio higher than other vessels, 4:1 to 4.75:1. The name came to be applied to faster-than-usual vessels (Howard 1979). Three masts, ship-rigged. Popular 1575-1645 in Spanish trade (Chaunu and Chaunu 1955).
14. Galleon. Largest vessels of Spanish build. Armed as warships or merchantmen. Ship-rigged, square sterns. Dominated Spanish trade together with naos after 1520's (Chaunu and Chaunu 1955).
15. Galley. Sail-oar hybrids that originated in Mediterranean. Lateen-rigged of varying size. Used by Spanish between 1565 and 1600 in Caribbean as coastal defense vessels (Hoffman 1980). Later designs in Gulf and Southeast were up to 60 feet, with 14 oars and 18 cannons (Fleetwood 1982).
16. Hooker. Hourque. Spanish supply vessel (McWilliams 1981). Rig unknown. Chaunu and Chaunu (1 955) show a lateen on the fore and mizzen masts. The main is square-rigged. The type is represented from just before 1550 infrequently to 1650 (ibid).

FIGURE E-2. A mid-sixteenth century galleon and galley. After a contemporary engraving.

Table E-1
(continued).

17. Ketch. Two roasted medium vessel, 70-130 feet in length (Wilson 1983). Foremast taller than main (ibid).
18. Launch. Small vessel utilized in conjunction with larger vessels. Howard (1979) describes them as rowed or sailed.
19. Longboat. Normally a ship's boat. Up to 52 feet in length in British examples (Howard 1979). Carvel built with small cannon in larger sizes.
20. Nao, NaviO. Originally a small ship with two masts - main and mizzen (Wilson 1983). Used throughout the Spanish period with term tending to mean ship-rigged vessels in later centuries (Chaunu and Chaunu 1955).
21. Pinnace. Similiar to a launch but generally longer (30-50 feet). Chapelle (1951) cites a variety of rigs. Originally a name for a small ship (Howard 1979).
22, Piragua. Shallow draft vessels, oarred with a large sail. The two utilized by the Spanish expedition of 1686-87 were 54 and 60 ft. in length, carried 20 oars and 25 men (Weddle 1987).
23. Pirogue. Dugout boat with seats for rowers and coxswain (Surrey 1916). Typically oar driven but could have simple sail rig (ibid).
24. Badeau. A general French word for "raft" or freight-boat e.g. generic classification.
25. Skiff. Smallest of ship's boats (Howard 1979). They were 20 feet in length (ibid). Carvel or clinker-built.
26. Traverser. McWilliams (1 981) translates the French term as "smack". Surrev (1916) says the term is general" like "bateau". Obviously they had keels and had" trouble in shallow waters (ibid: 63). Probably with one or two masts and variously rigged, 30 to 50 tons capable of Gulf travel.

Eighteenth Centurv

1. Bercha. Small Spanish vessel type of 1780's (Coker and Coker 1982).
2. Bermuda Sloop. (see illustrations **this** appendix).
3. Brig. Square-rigged, two-roasted vessel (Faye 194).
4. Cutter. Seat with slender lines, clinker-built with two to three masts fore-and-aft rigged (Chapelle 1951) and straight stem (Howard 1979).
5. Frigate. 18th century frigates carried armament on their upper deck unlike 17th century versions (lower deck) (Howard 1979). French versions were lightly built while British more robust. Bows rounded hence "the Frigate bow" as timbers carried up to forecastle deck height (ibid). Rated by number of guns (20-42).
6. Goleta, goleta de dos gavia, goleta de gavia. Schooner-type vessel with fore-and-aft rig coupled with square topsails e.g. a top-sail schooner (Faye 1940).
7. Paranzello. Double-ended, one-roasted, lateen-rigged boat (Faye). Evolved into New Orleans lugger.
8. Pink. Any sharp-sterned vessel (Chapelle 1951).
9. Polaos. Small Spanish vessel with square and lateen combination in its rig (Coker and Coker 1981).
10. Schooner. Developed off United States to utilize on and offshore winds (Howard 1979). Two principal classes-cargo (smaller, fuller lines) and sharper lined, taller-rigged smugglers, privateers (ibid; Faye). The classic fore-and-aft rigged ship up to six masts in later centuries.

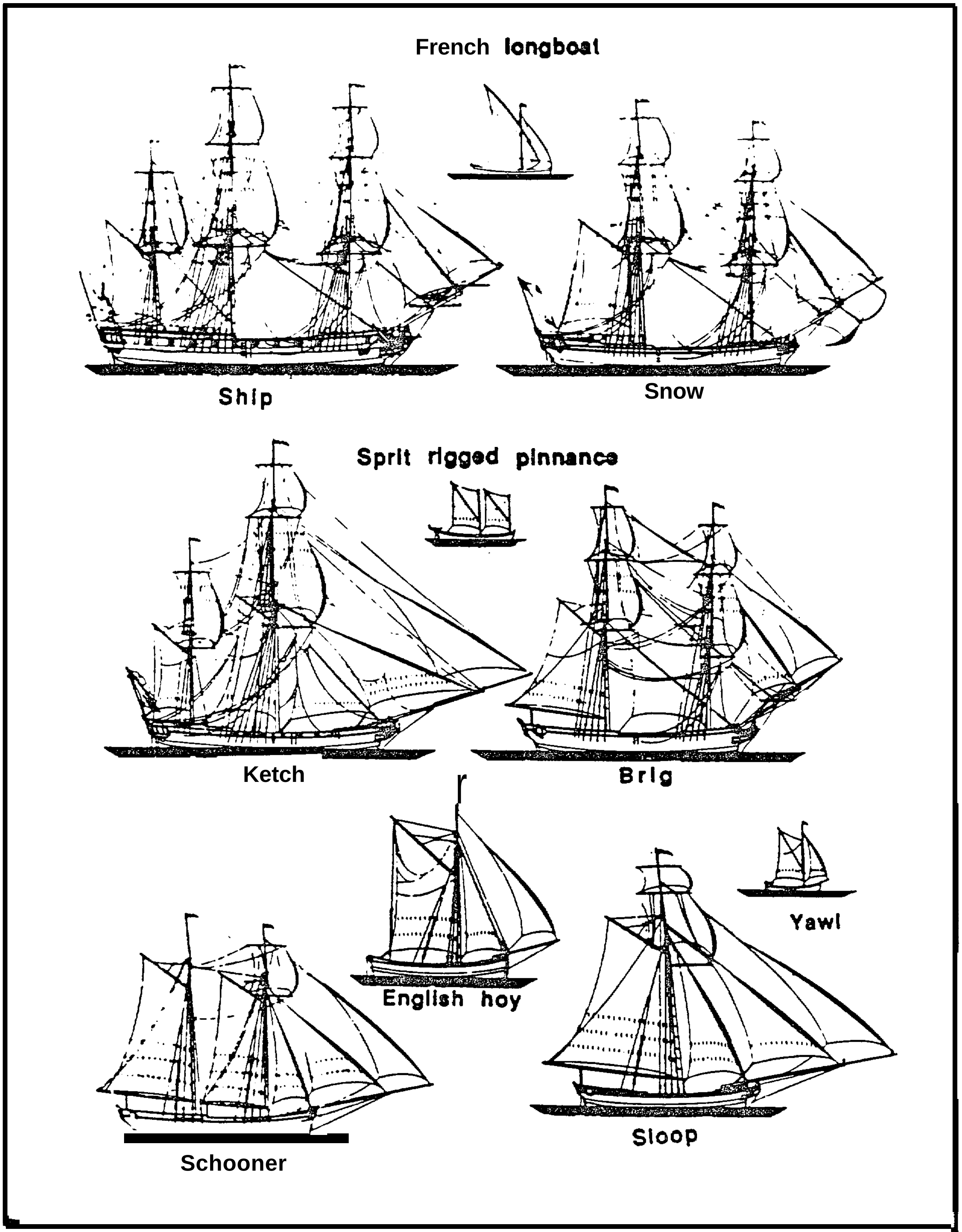


FIGURE E-3. Gulf of Mexico vessel types.

Table E-1
(continued).

11. Sloop. Name given to three kinds of vessels: single-masted sloops, 2-roasted sloops (snows, brigs and ketches) and 3-roasted ship sloops. Snows had no mizzen mast and ketches no foremast. Many sloops had an unbroken sheer of their main deck (Howard 1979). Sloops were square-rigged.
12. Saetia. Two-roasted, lateen sail rig (Coker and Coker 1981).
13. Snow. (see sloop).
14. Xebec. A falouche with three masts (Faye 1940).
15, Yawl. Ship's boat much like skiffs, pinnaces, and long boats. Rigged for oars and sails (l-2 masts) (Chapelle 1951).

Nineteenth Century to Twentieth Century

1. Baltimore Clipper, Chesapeake Bay origin with "bow turned inside out," e.g. clipper bow, raked schooner-rigged masts, and narrow lines. Probably developed out of Chesapeake log canoes."
2. Bark. Vessels with all masts square-rigged except mizzen. An example is the restored ELISSA, Galveston, Texas.
3. Barkentine. Foremast is square rigged with fore-and-aft rigs on all others. Similiar to schooners (Wilson 1983).
4. Biloxi atboat. Shallow-draft draft with centerboards used primarily for recreation. Single mast (Chapelle 1976).
5. Biloxi Lugger. Evolved out of falouche (see Faye). Characterized by sharp bow, moderate sheer, straight keel, low deadrise, large center-board, broad stern, post-rudder outboard, cabin and cockpit. Lug-rigged (Chapelle 1951; 1976).
6. Crewboat. Late 20th Century monohull, typically steel or aluminum with up to four propellers. Built for speed (up to 35+ knots). Used in offshore petroleum industry. All designs of Gulf origin.
7. Cutter. Term evolved to mean fast Revenue (U.S. Coast Guard) vessels - sail or steam (Wilson 1983).
8. Flattie. Flat-bottomed, sloop-rigged boat used on Gulf coast in 1880's (Wilson 1983). Around 17 feet long, 2 1/2 feet draft, skeg and out board rudder (Chapelle 1951),
9. undalow. Also called "scow". Flat or slight v-bottom with sloop or schooner rig. Flat ends, center board, trunk cabin and cuddy (Chapelle 1951). Became common in Gulf after 1840 (Wilson 1983) - 25 to 35 feet in length.
10. Key West Smackee. A fishing sloop, 17-26 feet in length, square stern, outboard rudder and shallow draft (Wilson 1983).
11. Louisiana Oyster Sloop. A centerboard sloop with straight stern. Hull with large sheer over a length of about 36 feet. Common in Morgan City eastward (Chapelle 1976).
12. Packet. Generic name for sail or steam powered vessels on regular service line.
13. Pilot Boat. Sloop or schooner rigged vessels up to 75 feet long used by bar pilots to meet inbound vessels (Wilson 1983). A modified Chesapeake form was used on the Gulf Coast (Chapelle 1976).
14. Schooner. This vessel design dominated coastal traffic in 19th century. It's use continued well into the 20th century. Some Civil War Schooners could raise their

Table E-1
(continued).

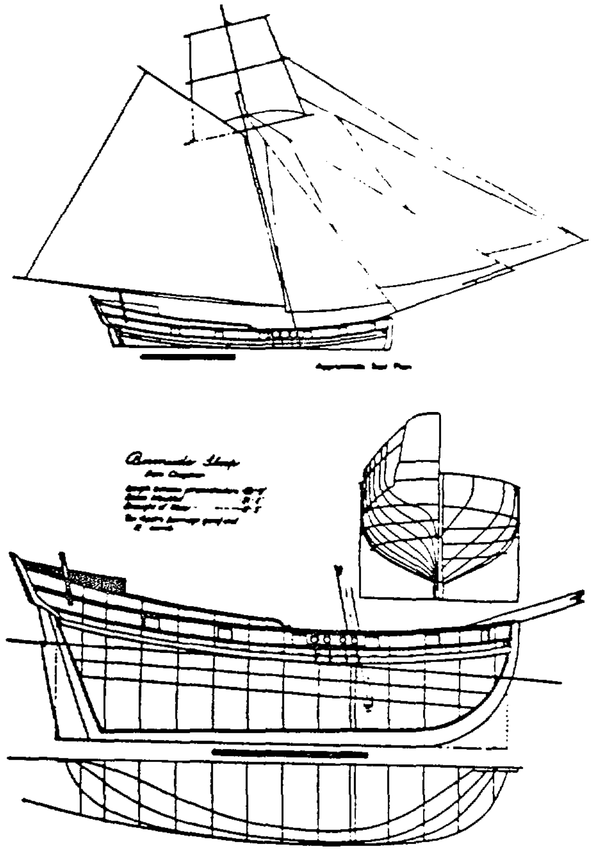
centerboards (Fleetwood 1982). It's use continued well into the 20th century (Nevins 1946: 5; Sea History 1986). Schooners remained in fishing fleets up to 1933 when law changes permitted oyster dredging with motor vessels (Mistovich *et al* 1983).

15. Snapper Boat. Based on auxiliary schooner design with rear wheel house, flush deck, two masts. The schooner type boats still fish the Gulf although primarily engine powered.
16. Scow. See gundalow.
17. Sharpie. Flat-bottomed with a sharp-bow (hence the name) up to 65 feet long. Various rigs (Chapelle 1951).
18. Shrimper. Vessel developed 1915-1925 relying On engine power alone. The design's origin was the familiar hugger but without a sail rig. The first of this class was the EAGLE built in Bayou La Batre, Alabama in 1925 (Wilson 1983). Early designs were wooden round or v-bottom with a large amount of sheer. After 1937 and the discovery of offshore shrimp grounds (Kniffen 1969) large vessels with two other trawls became standard. Wheel houses moved forward and steel hulls are most common today.
19. Skipjack. Fishing design up to 25 feet in lenth. Round hull with sloop rig in Chesapeake forms. V-bottoms were either "skipjacks" or "bateaus". (Chapelle 1951; 1976).
20. Steamboat, sidewheel paddle (river). This vessel design had a shallow draft, light hull typically using a high pressure steam engine or engines driving two side paddles. Developed as riverine packets they were common in the mid-late 19th century coastal trade.
21. Steam boat, sternwheel (river). The sternwheel design eventually supplanted the sidewheel design on rivers although this proved less propitious on the Gulf where waves could have the sternwheel out of the water a good bit of the time. Popular due to the narrower breadth which allowed their use on bayous, canals and coast.
22. Seamship, paddle. Vessels with ship-hulls e.g. deep draft, keels and balanced-sing rudders. Early vessels (mid - 19th century) were all wooden but iron and steel hulls supplanted wood by the turn of the century. Power was by low pressure steam engines in contrast to river-design boats. Some of the mid - late 19th century vessels maintained a sail rig - typically fore-and-aft or schooner type.
23. Steamship, Screw propellor. Deep draft, keeled hull but with propellor. Supplanted paddle designs by late 19th century due to greater efficiency in propulsion. The classic cargo ship design after 1914 was a steel hull separated by watertight bulkheads, deckhouse, a mid-ships and masts rigged as booms for unloading. This carried through the second World War in Liberty Ship design. Common size was 16,000 dwt (dead weight tons); lengths of 350 feet.
24. Supplyboat: mudboat. Vessel design of Gulf origin. Evolved to serve offshore oil industry. Diesel powered, steel hulls with very low freeboard aft of a pilot house/crew section. This aft deck is over twice the length of the shorter, higher bow section and is for deck cargo.
25. Submarine (U-boat). German submarines of World War II. Operated in Gulf of Mexico 1942-1944.
26. Tanker. Steamers designed to carry petroleum began in 1880's (Haviland 1978:). Iron or steel hulled, screwdriver. Early tonnages for these vessels ranged from 482 to 8,039 (1 905). Up to 1956 the largest tanker was only 56, 089 dwt

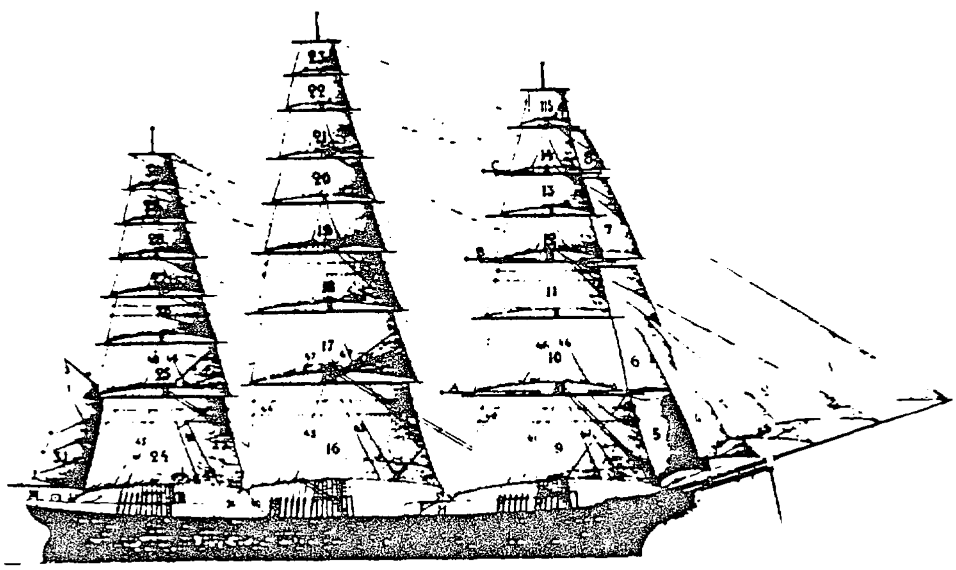
Table E-1
(continued).

(Center for Wetland Studies 1972). Principal targets of German submarines in Gulf of Mexico of **World** War II (Róhwer 1983).

27. Towboat. Based on tugboat designs, with deep hulls, sharp bow, powerful engines - first steam then diesel. These vessels have evolved into push boat designs with square bows. Pointed bows have survived on ocean going forms for use in the offshore.

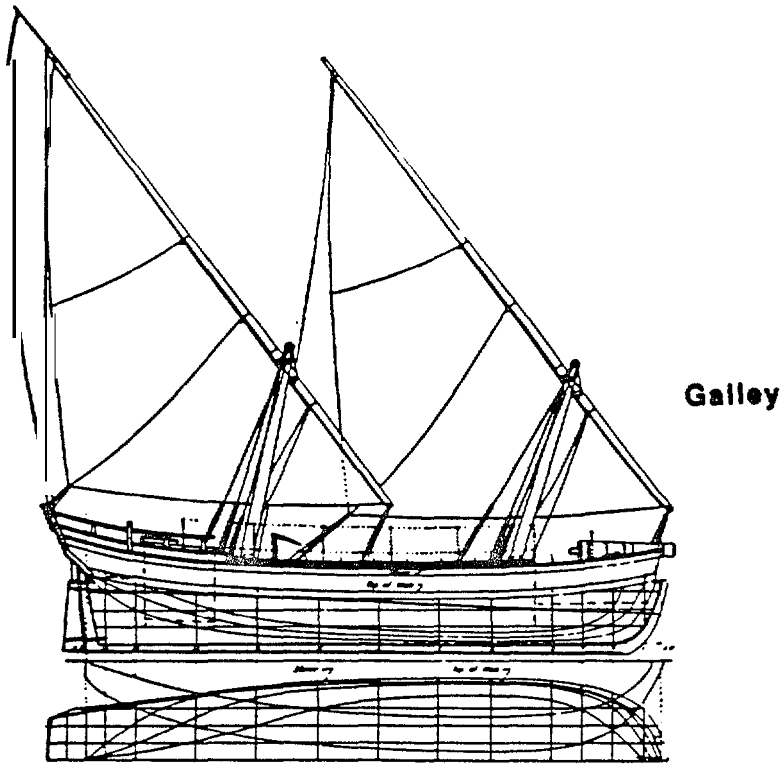


Bermuda Sloop



Ship

FIGURE E-4. **Gulf of Mexico vessel types.**



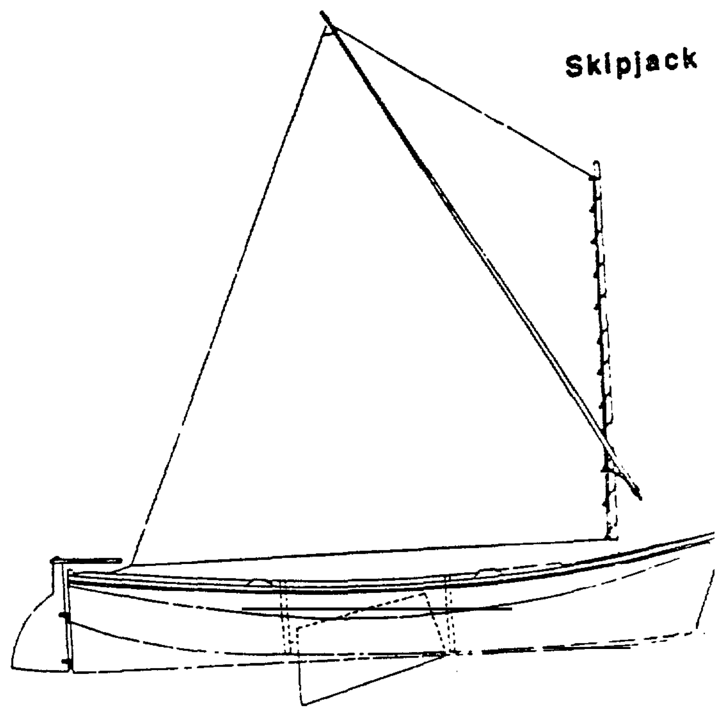


FIGURE E-5. **Gulf of Mexico vessel types.**

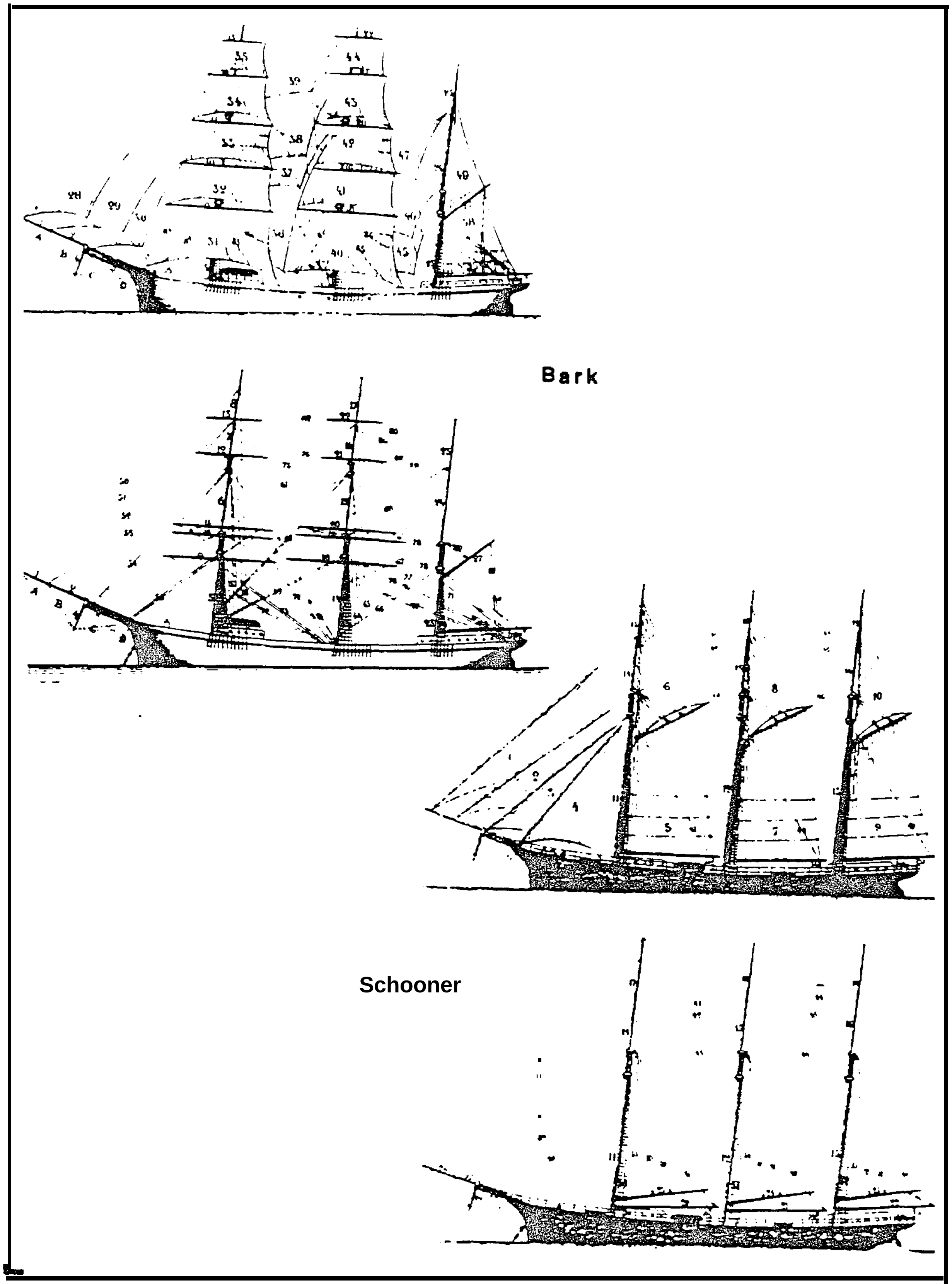
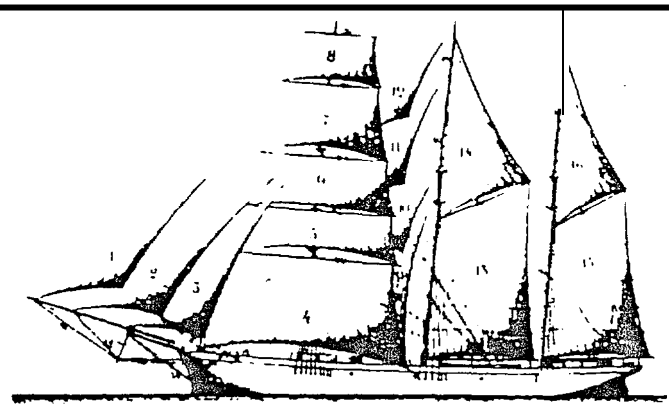
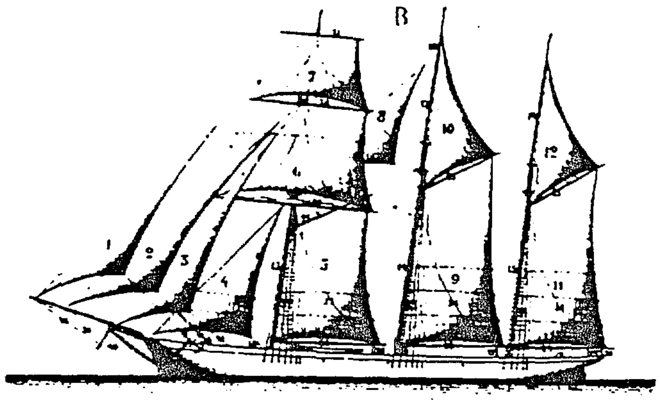


FIGURE E-6. Gulf of Mexico vessel types.

Barkentine





Topsail Schooner

Brig

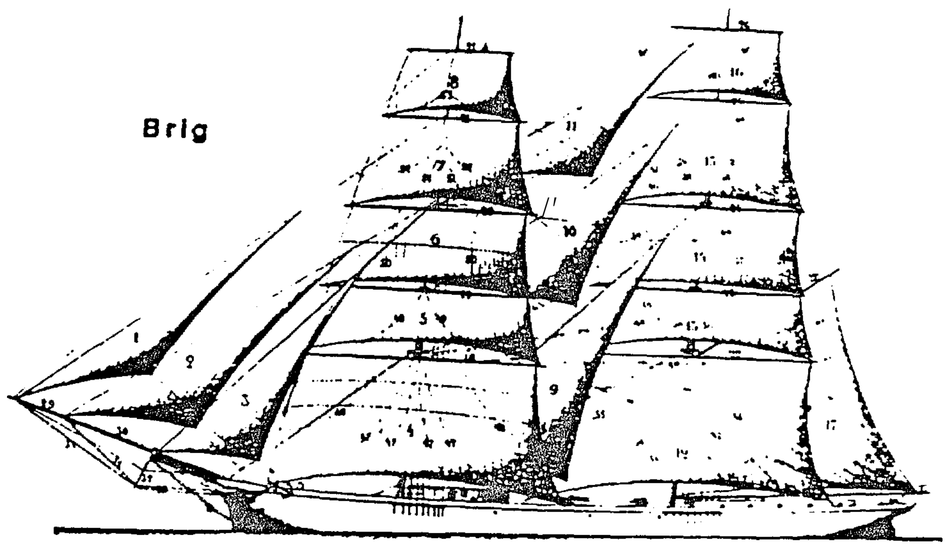
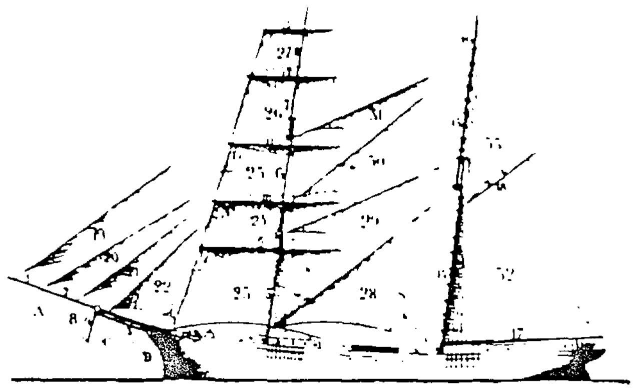
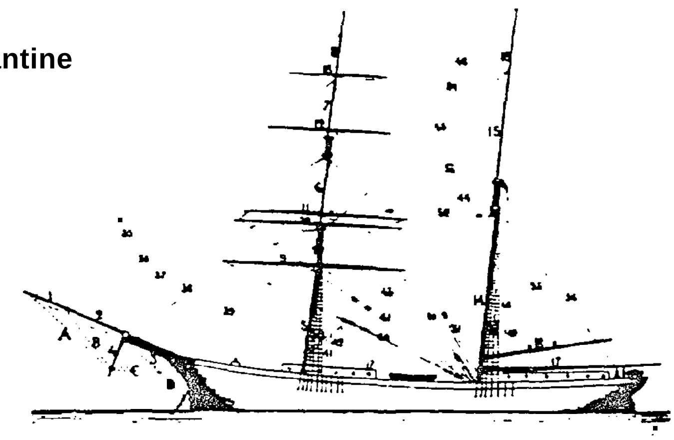


FIGURE E-7. Gulf of Mexico vessel types.



Brigantine



Mall-Passenger

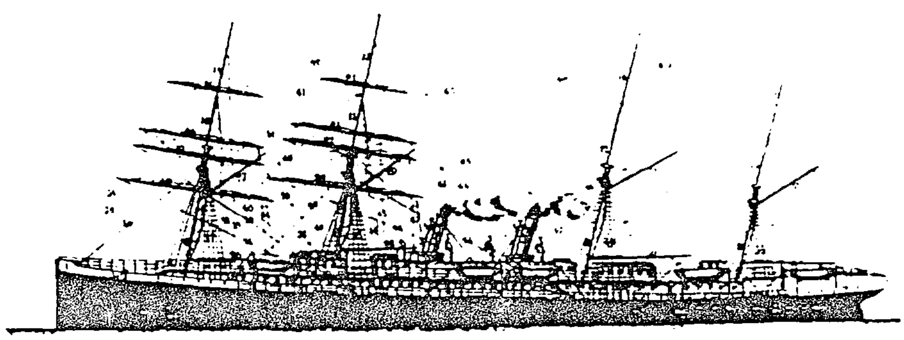


FIGURE E-8. Gulf of Mexico vessel types.

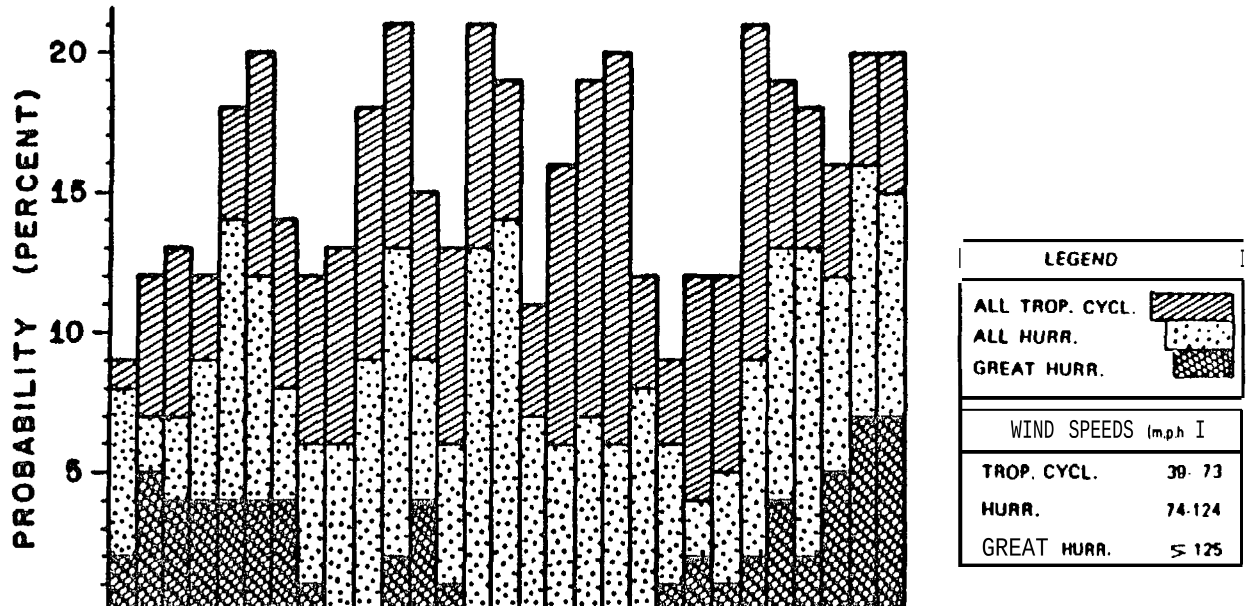
APPENDIX F

Hurricane Tracks and Incidence in the Gulf of Mexico

RISK OF TROPICAL CYCLONES

U.S. Gulf of Mexico Coastline

This histogram ond table show the probability (percentage) that a tropical storm, hurricane, or great hurricane will occur in any one yeor in a 50 mile segment of the coastline.



COASTAL SECTOR *	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
ALL TROPICAL CYCLONES	9	12	13	12	18	20	14	12	13	18	21	15	13	21	19	11	16	19	20	12	9	12	12	21	19	18	16	20	20
ALL HURRICANES	8	7	7	9	14	12	8	6	6	9	13	9	6	13	14	7	6	7	6	8	6	4	5	9	13	13	12	16	15
GREAT HURRICANES	2	5	4	4	4	4	4	1	–	–	2	4	1	–	–	–	–	–	–	–	1	2	1	2	4	2	5	7	7

TX | LA | MI–AL | FL

FIGURE F-1. Risk of Tropical Cyclones - U.S. Gulf of Mexico Coastline.

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3

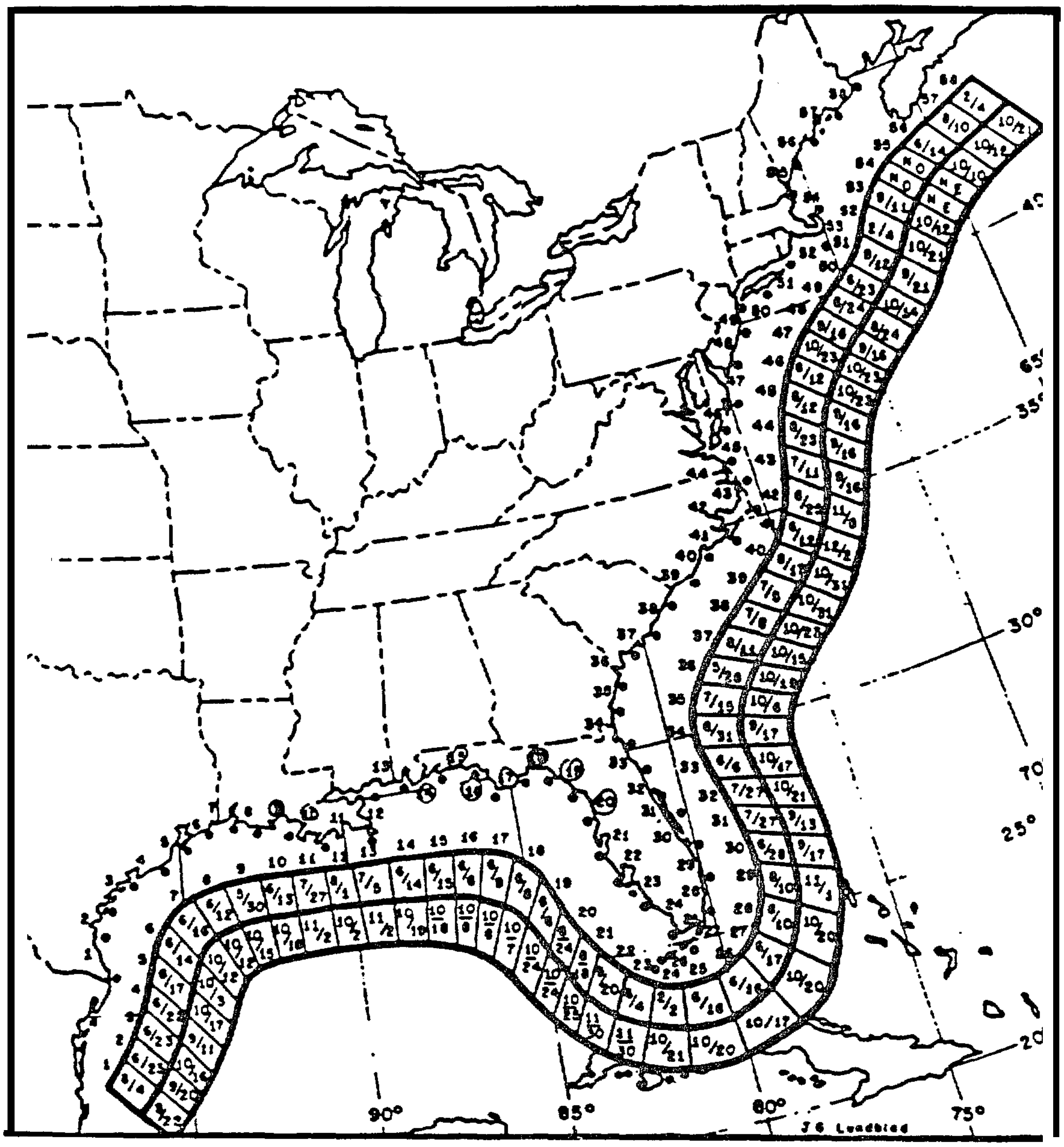

FIGURE F-2, **Tropical Storm Incidence Along the** Gulf **and Atlantic Coasts. Coastal segments indicated are approximately 50 nautical miles in length. Month and day in box indicates the earliest and latest date of landfall for tropical cyclone occurrences for each segment from 1886-1970.**

Table **F-1.**

Chronological List of Tropical Storms
LIST OF TROPICAL STORMS OF THE GULF OF MEXICO FROM 1494 TO 1900.

Date of Storm	Principal Places Affected, and Remarks
1559, September 19	Mobile and Pensacola. "Great Tempest" lasted 24 hours.
1565, September	East coast of Florida.
1566, September 16	East coast of Florida.
1674, June	Bay of Campeche.
1711, September 11-13	New Orleans. Destroyed St. Louis Cathedral.
1722, September 12-13	New Orleans. 'Everything in the port was lost.' Houses, church and hospital destroyed.
1723, ________	New Orleans. "A remarkable hurricane nearly destroyed all buildings."
1736, ________	Pensacola. Village swept away.
1740, September 12	Mouth of Mississippi, Pensacola.
1759, September	Gulf of Mexico, Florida. XII.
1766, September 14	Galveston.
1766, October 22	Pensacola. Spanish fleet en route from Vera Cruz to Havana wrecked.
1769, August 30	Florida.
1769, October 29	Florida.
1779, October 7-10	New Orleans.
1780, August 24	New Orleans. Swept over the province of Louisiana, destroying crops, tearing down buildings and sinking every vessel and boat afloat on the Mississippi River.
1780, October 16, 17	Cuba. Solano's storm. XII.
1787, August 15	Florida.
1800, August	New Orleans.
1811, ________	New Orleans.
1812, August 19	New Orleans. Possibly same as preceding.
1813, August 19	Gulf coast.
1818, ________	Galveston. Four of Lafitte's vessels sunk or driven ashore.
1819, August 25 to 28	Louisiana and Alabama.
1821, ________	New Orleans.
1822, July 11	Mobile.
1831, June 10	Florida.
1831, June 23	Gulf of Mexico.
1831, August 18	Gulf coast, near mouth of Rio Grande.
1833, October 16-19	Cuba, Gulf of Mexico.
1834, September	South Texas.
1835, August 12-18	Antigua, Cuba, Galveston. At Antigua the barometer fell an Inch in 1 hour and 27 minutes.
1837, August 31	Western Florida.
1837, September 27-October 10	Gulf of Mexico, "Racer's Storm," X, XIII.
1838, ________	Lower Texas coast.
1839, November 5	Galveston
1840, ________	Lower Texas. Villages destroyed at mouth of Rio Grande.
1842, August 30 to September 9	From Atlantic moved due west across Florida to Tampico. September 4 at Havana, barometer 28.93 inches. XIII.

Table F-1
(continued),

1842, September 18-22	Gulf of Mexico.
1842, October 5	Galveston.
1842, October 2-10	Gulf of Mexico, Bermuda. Not same as preceding storm.
1844, August 4-6	Mouth of Rio Crande. Not a vestige of a single house left at Brazes Santiago or at mouth of river. About 70 lives lost.
1844, September 1	East Gulf.
1844, October 12	Florida Straits.
1846, ________	New Orleans.
1846, September	Tampa.
1848, October 16	Tampa.
1851, September 18	Gulf of Mexico.
1852, October 9	Florida.
1854, September 16-19	Matagorda, Tex.
1854, September	Galveston. Probably same as preceding.
1856, August 9-12	Louisiana coast. XIII.
1856, August 27-September 2	Cuba to Mobile. Havana barometer 28.62.
1860, August 11	Mobile.
1860, September 15	Mobile.
1865, September	Western Louisiana.
1865, October 22, 23	Cuba to Louisiana coast.
1866, ________	Galveston.
1867, October 1-3	Galveston.
1870, July 3	Mobile.
1871, June 1-4	Texas coast. Barometer at Galveston 29.S1.
1871, June 9	East Texas coast.
1871, October 2-3	Galveston.
1874, July 2-4	Gulf, Indianola, Tex.
1874, September 3-6	Gulf coast of Mexico. Moved north-northwestward into Texas.
1875, September 14-19	Cuba, Gulf, Indianola, Tex. II, XIII.
1876, October 7-10	Gulf, Florida.
1877, September 15-21	West Gulf. Louisiana, Georgia.
1878, July 1-3	Florida.
1878, August 13-17	Caribbean Sea and Gulf of Mexico.
1878, October 9-13	Gulf, North Florida.
1879, August 20-23	Yucatan, Texas coast.
1879, September 12-22	Caribbean Sea, Florida.
1879, October 11-15	Caribbean Sea, western Florida.
1882, September 2-15	Turks Island, Cuba, Gulf coast. Wind reached 92 miles NE. at Port Eads, La.
1882, October 8-12	Grand Cayman Island, Cuba. Florida. Town of Pimr del Rio practically all destroyed.
1885, September 17-21	Brownsville, southern Louisiana, Georgia.
1885, September 24-30	Gulf, Louisiana.
1885, October 10-11	Florida.
1886, June 13-14	Sabine, Tex. Inundation. XIII.
1886, June 15-20	Yucatan Channel, Florida. Much damage at Cedar Keys Wind 68 miles east.
1886, June 27-31	Yucatan, Florida. Great destruction in the Apalachicola-Tallahassee section.
1886, July 14-19	Yucatan Channel, Florida.
1886, July 30	East Gulf.
1886, August 13-20	East Caribbean, Cuba, Indianola, Tex. Very severe in Cuba; destroyed Indianola. II, X111.
1886, August 12-18	Eastern Caribbean, Cuba, Gulf.

Table F-1
(continued),

1886, September 15-25	Martinique, Jamaica, Brownsville, Tex. XIII.
1886, October 8-13	Western Cuba, extreme East Texas. Center passed near Sabine Pass, Tex. Johnson's Bayou and Sabine pasa inundated: overflow extending 20 miles inland. Nearly every house moved from its foundation. One hundred fifty lives lost. Second overflow at this point in 1886; first occurred in June. X111.
1887. July 20-28	Martinique, Yucatan, Apalachicola.
1887, October 9-24	Recurved in Gulf.
1887, October 29-November 8	Gulf, over Florida to Atlantic.
1887, November 27-December 6	Described loop in Bahamas and turned northeastward into Atlantic.
1888, June 17	North Texas coast.
1888, July 5	Galveston.
1888, August 14-24	Florida, middle Gulf coast. Wind estimated at 90 miles at New Orleans.
1888, September 23-27	Florida Straits, Atlantic.
1889, June 15-25	Extreme western Cuba, Florida.
1889, September 12-26	Guadaloupe, west Gulf.
1891, July 3-13	Bay of Campeche, Texas-Louisiana costs.
1891, October 1-9	Puerto Rico, Haiti, Cuba, Florida.
1892, June 10-16	Southern Florida.
1892, September 9-17	Middle Gulf coast.
1892, September 25-27	Bay of Campeche, Mexico.
1892, October 21-31	Gulf, Florida.
1893, September 6-10	Gulf of Mexico.
1893, September 27-October 6	Louisiana. Reached Gulf coast on October 1 and 2. Wind estimated at 100 miles an hour. Loss of life placed at 2,000. XiII.
1893, October 20-23	Southern Florida, Middle Atlantic coast.
1894, August 6-8	Kiddie Gulf coast; of small force.
1894, October 1-13	Western Caribbean Sea, Gulf and Atlantic coast states. Moved northeastward inside coast line. Winds exceeded 80 miles an hour at some places.
1895, August 16	Middle Gulf coast. Of slight force.
1895, August 22-29	Caribbean. Gulf, near mouth of Rio Grande.
1895, September 28-October 15	Yucatan, Florida Straits, Atlantic. Of slight intensity.
1895, October 2-7	Gulf, southern Florida, Bermuda.
1895, October 13-16	Bay of Campeche, southern Florida, Atlantic.
1896, September 22-October 1	Windward Islands, extreme western Cuba, Florida. Increased in intensity as it reached Florida and moved through Atlantic States, inside coast line. Center passed over District of Columbia. Principal damage in Florida. Total $7.000,000; 114 lives lost. XIII.
1897, September 11-13	Gulf, Louisiana.
1898, September 12-25	Yucatan, Louisiana.
1898, September 21-28	Western Caribbean, Yucatan, east Texas coast. Not of much force.
1898, October 10-26	Caribbean Sea, western Cuba, Florida.
1899, October 2-9	Gulf, Florida, Atlantic. Of small force.
1900, August 27-September 22	Atlantic, Haiti, Cuba, Galveston. Disaster at Galveston, Sept. 8. 11, XIII.
1900, October 9-13	Western Caribbean, Yucatan, Gulf, Atlantic coast. Not of much intensity.

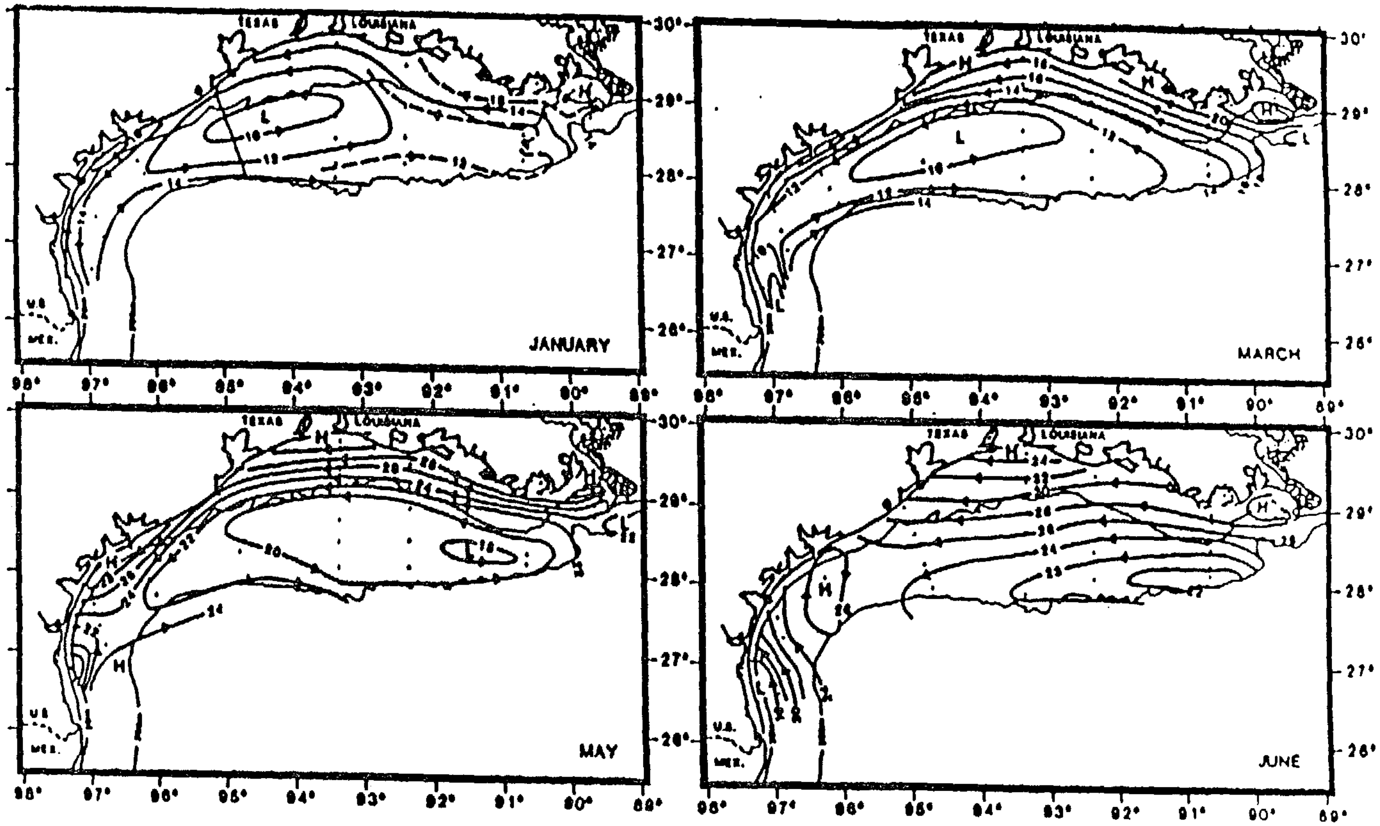

FIGURE F-3. Monthly mean streamlines of surface flow as indicated by geopotentall anomaly (dyn cm or 10-1 Jkc surface relative to 70 db or 0.70 MPa for January, March, May, and June based on data taken aboard 1963, 1964, and 1965 (from Cochrane and Kelly 1986).

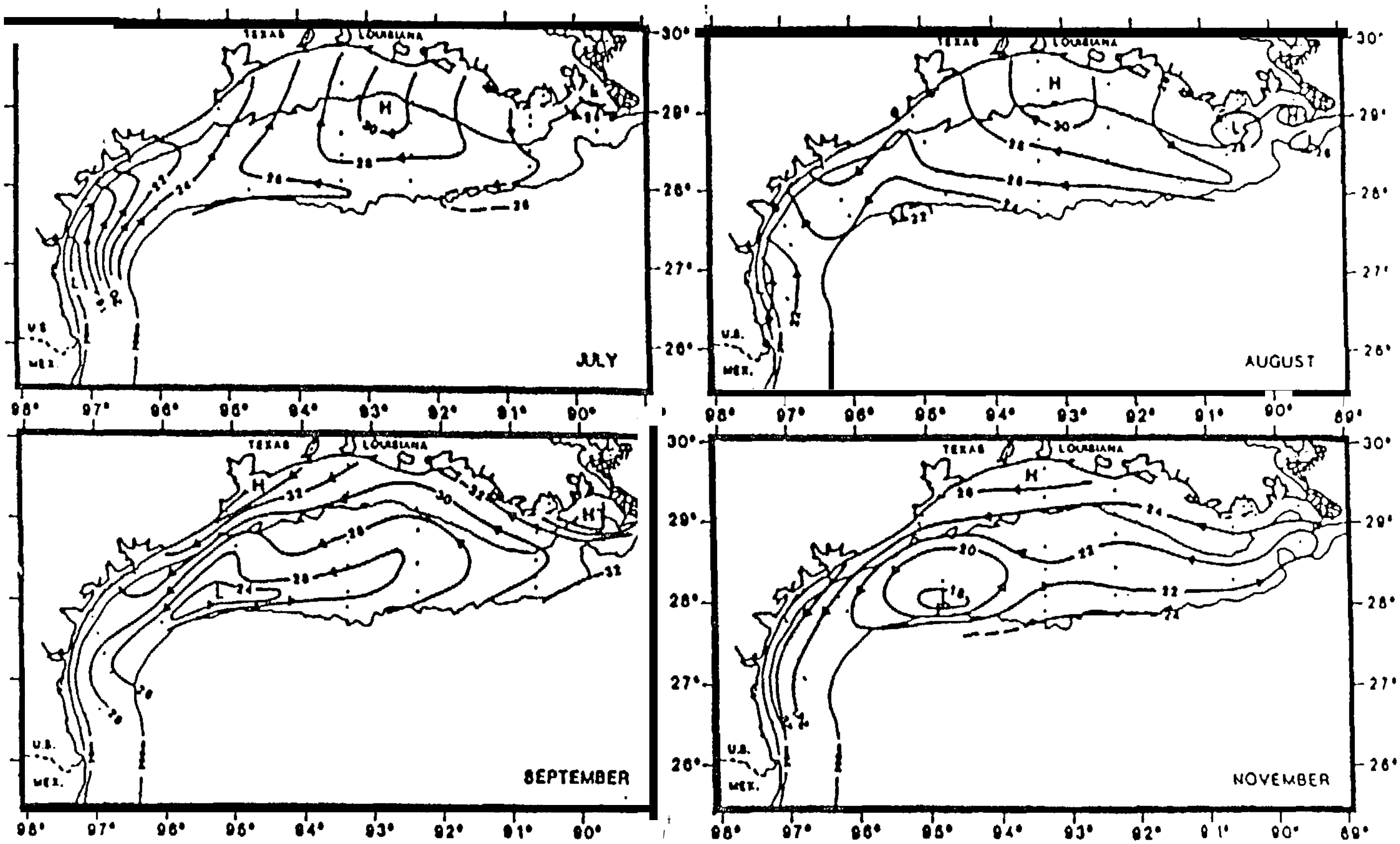

FIGURE F-4. Monthly mean streamlines of surface flow as Indicated by geopotential anomaly (dyn cm or 10-1 Jkc surface relative to 70 db or 0.70 MPa for July, August, September, and November based on data taken GUS III In 1963, 1964, and 1965 (from Cochrane and Kelly 1986).

Table F-2.

Frequency and Duration of Frontal Passages on the Texas/Louisiana Shelf, 1965-1972 (from: DiMego et al., 1976).

Month	Passages/Month	Frontal Duration (Hours)
January	9	24
February	9½	21
March	8	24
April	6½	27
May	4½	30
June	2	24
July	2	24
August	2	42
September	3	48
October	6	30
November	7	24
December	9	30

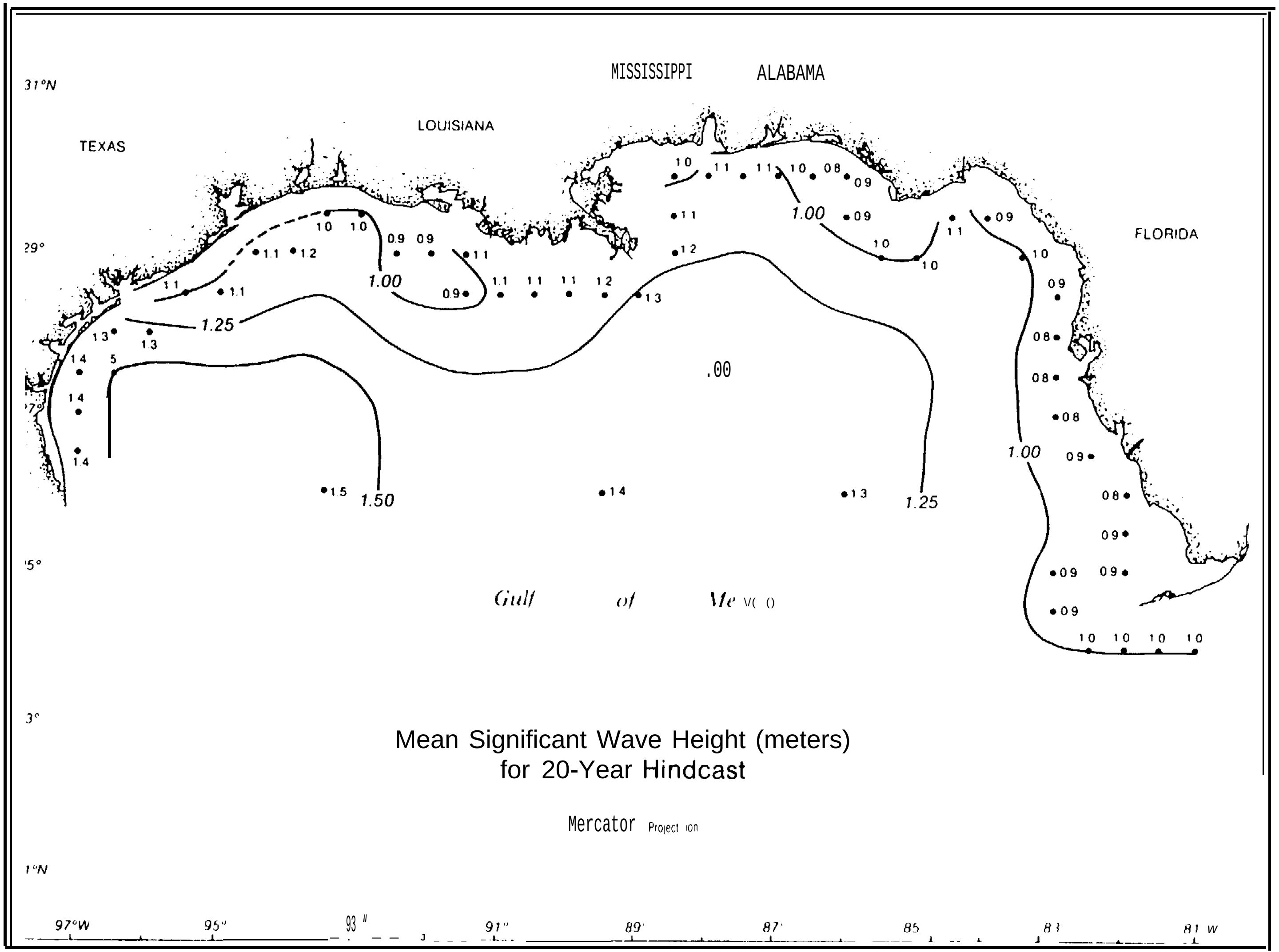

Figure F-5. Mean Significant Wave Height (meters) for 20-Year Hindcast.

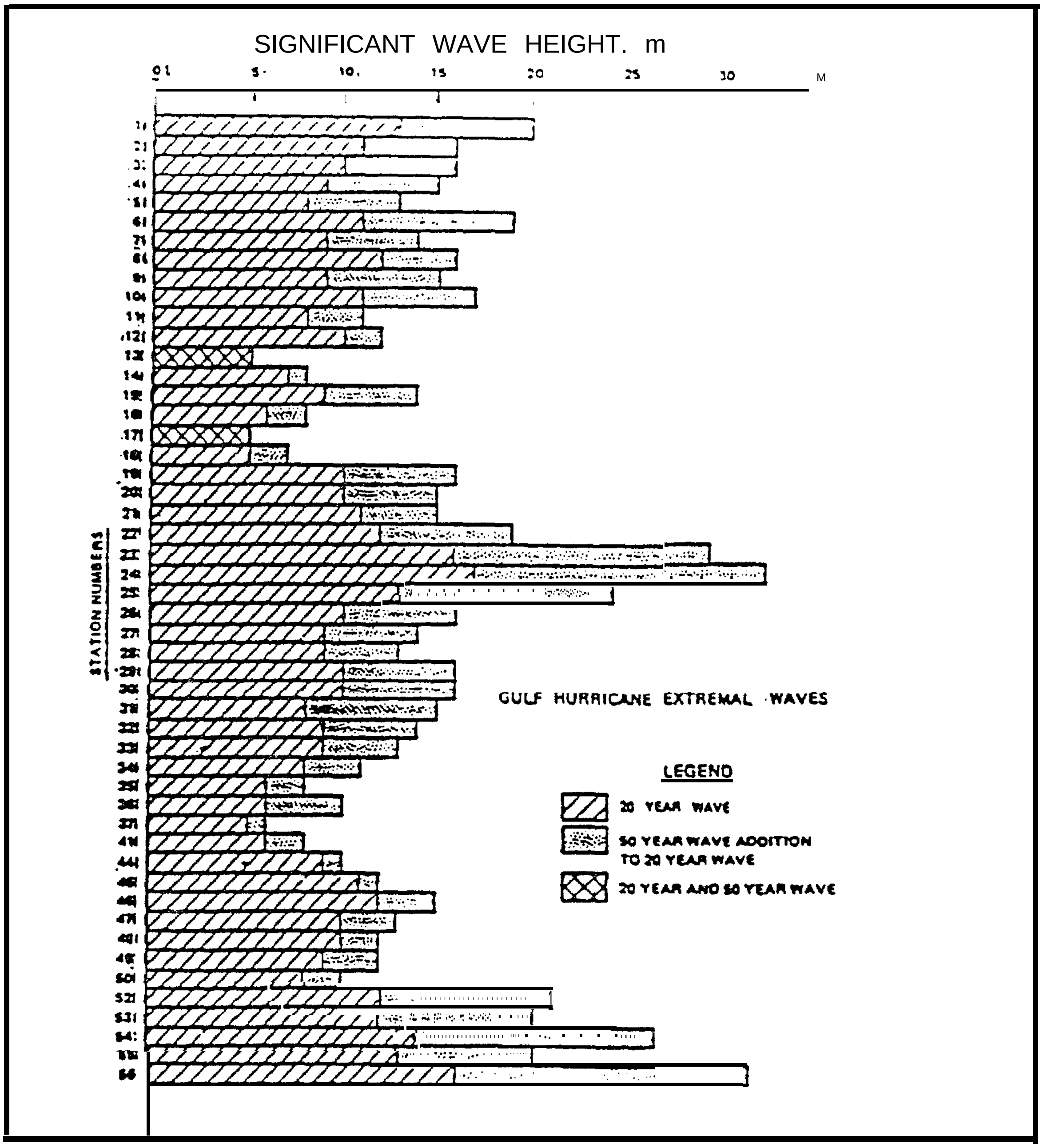

FIGURE F-6. **This histogram shows the 20 yr and 50 yr extremal waves that were calculated for each of the locations shown in Figure F-7.**

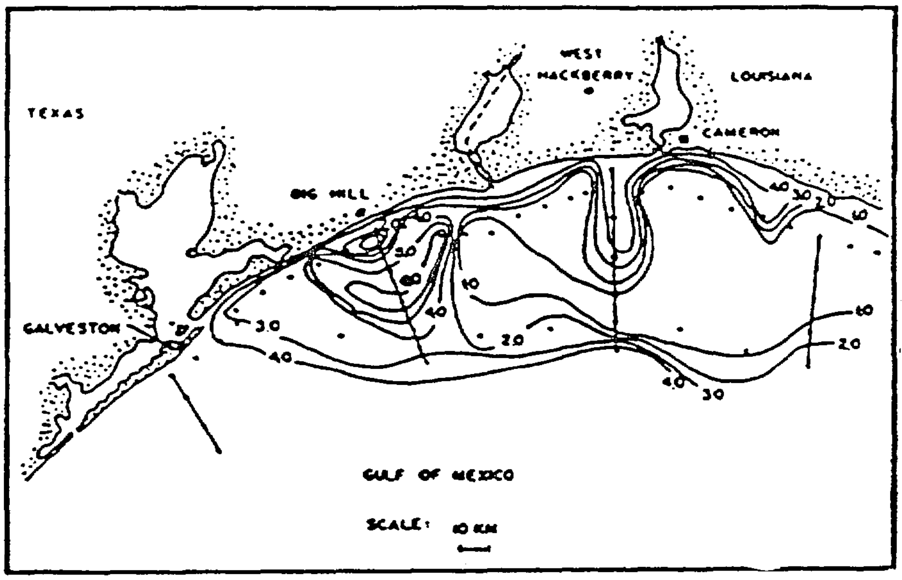

FIGURE F-8. **Dissolved oxygen concentrations (mg/l) of the bottom water on 9 to 10 July 1984 (From Pokryfki and Randall 1987).**

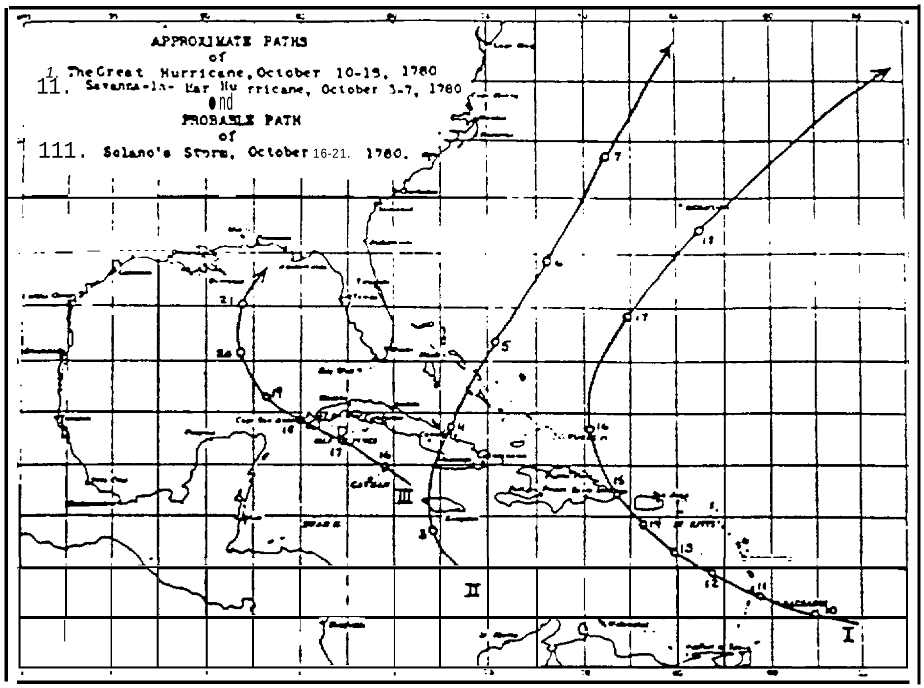

FIGURE F-9. **Paths of the hurricanes that occurred In the year** 1780. **Courses of the "Great Hurricane" and the "Savanna-la-Mar Hurricane," as determined by Colonel Reid. Probable path of "Solano's Storm" as deduced from observations on ships of the Spanish fleet en route from Havana *to* attack Pensacola.**

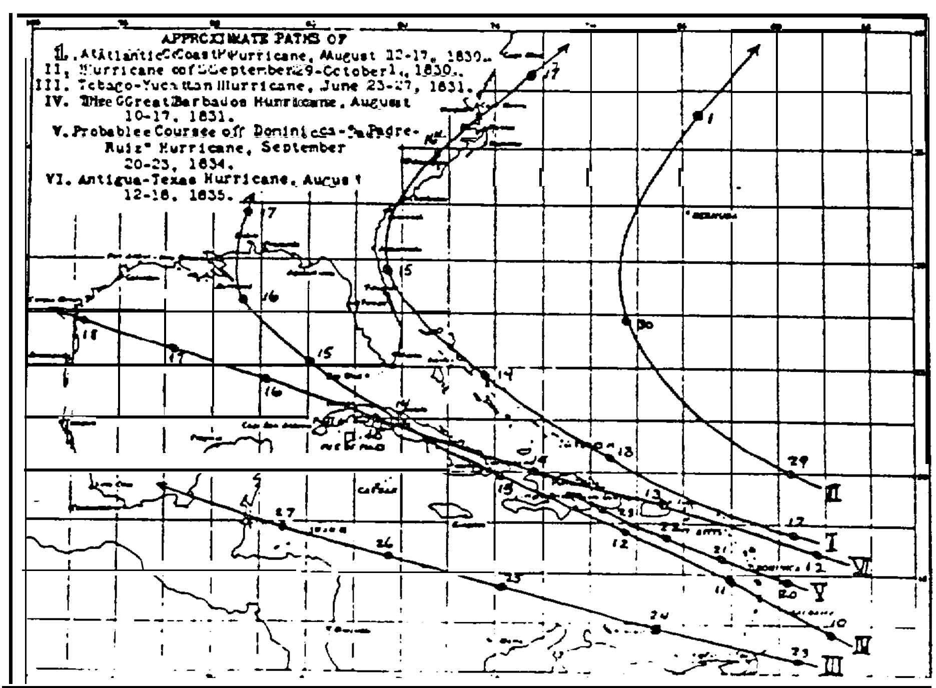

FIGURE F-10. **Path followed by center of the Great Barbados hurricane of 1831, and five other hurricanes of the same period.**

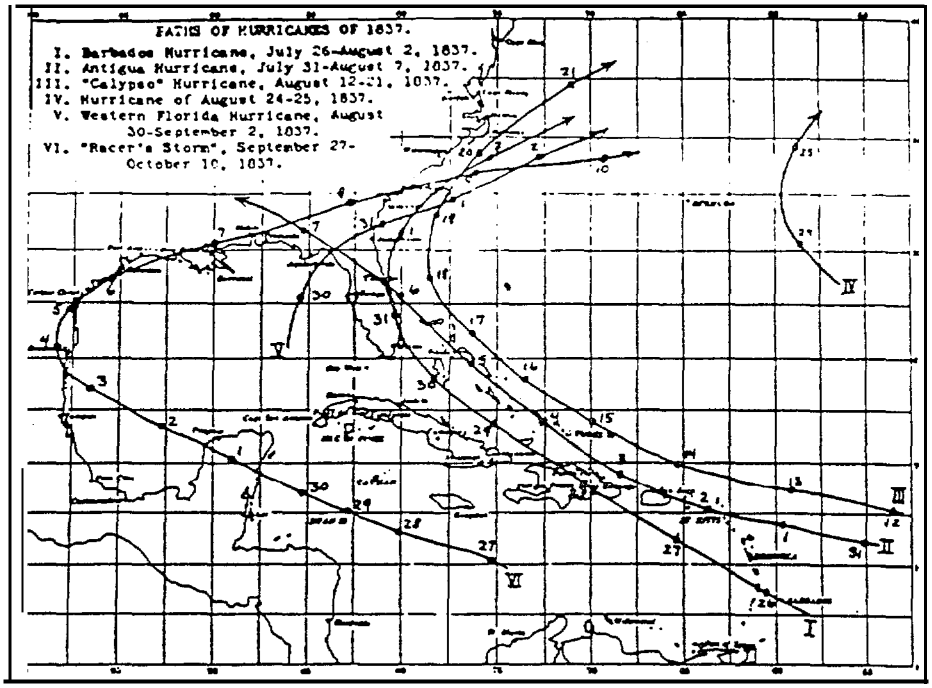

FIGURE F-17. **Track of "Racer's Storm" and five other hurricanes of 1837.**

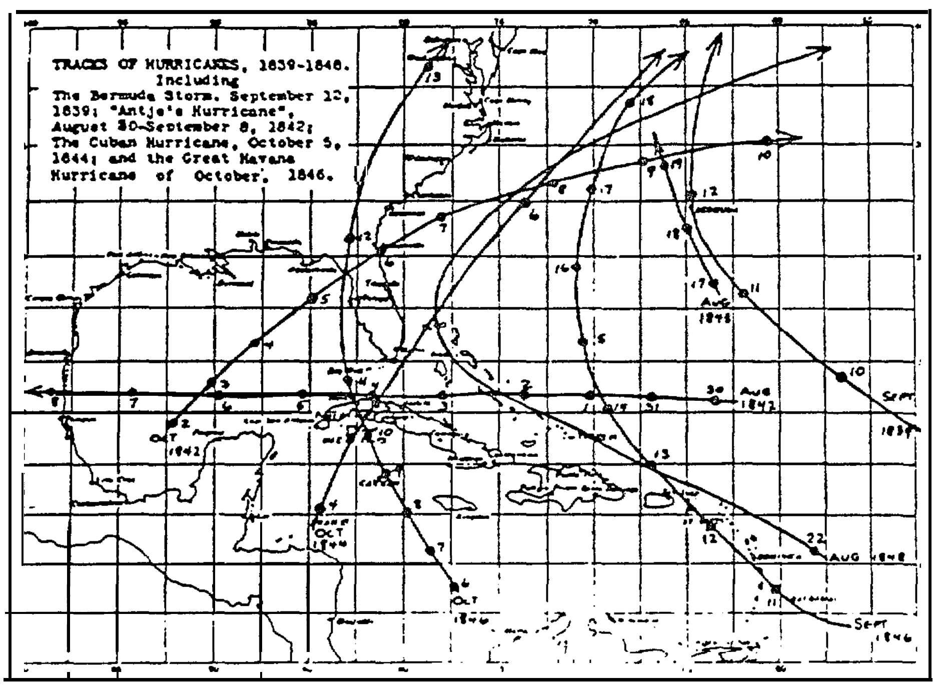

FIGURE F-12. **Tracks of eight hurricanes during the ten-year period, 1839 to 1848, including the Bermuda Storm, Antje's hurricane, and the Cuban and Great Havana hurricanes.**

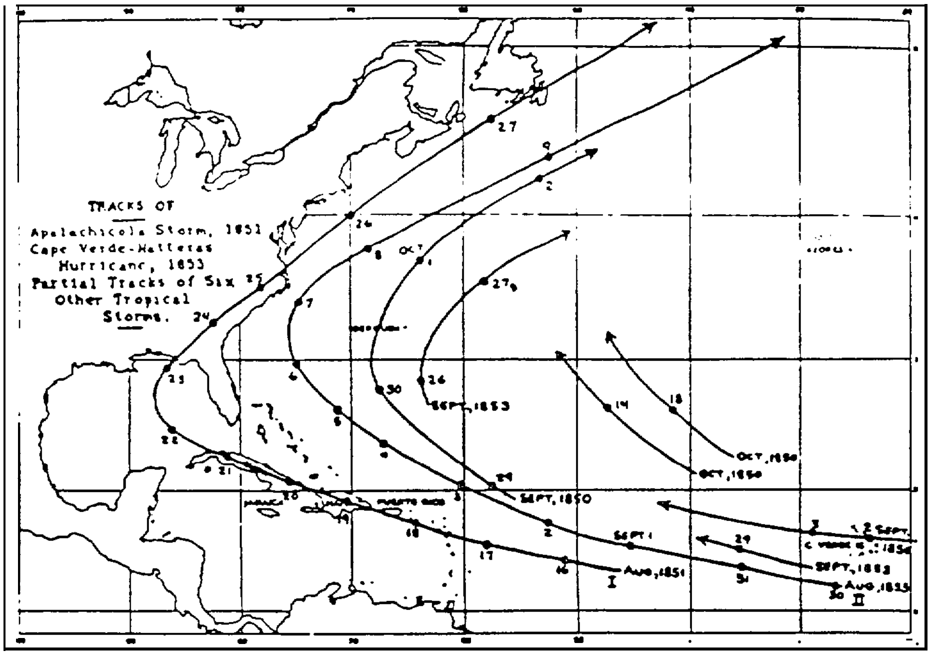

FIGURE F-13. **Track of the Cape Verde-Hatteras hurricane, the first to be traced from the region of the Cape Verde Islands to the vicinity of the Atlantic coast, also of the Apalachicola Storm, and six other hurricanes of the same period.**

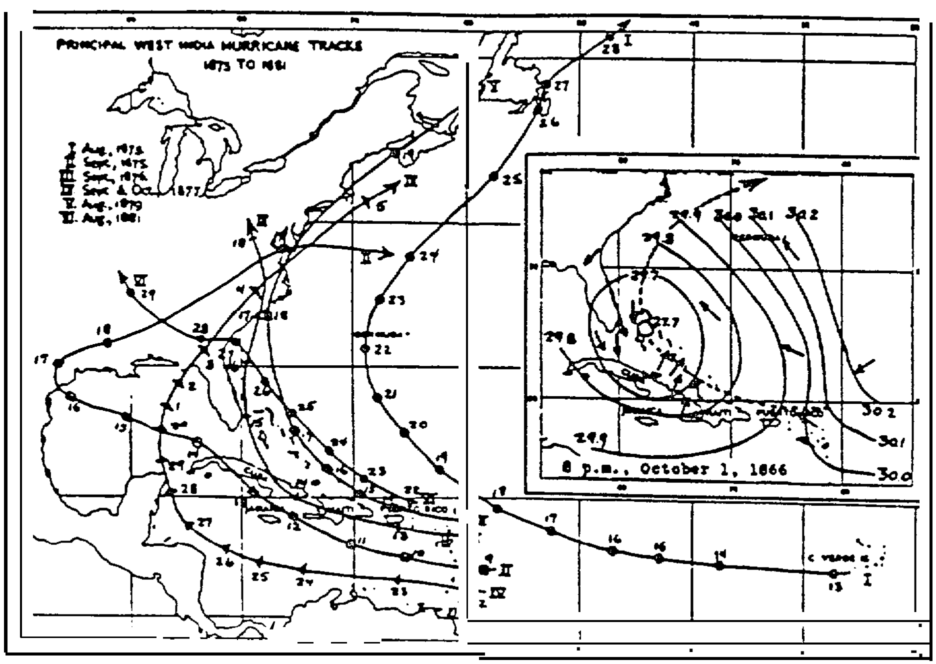

FIGURE F-14. **Tracks of principal West India hurricanes, 1$73 to 1881. Inset shows wind direction and pressure map of "Great Bahama Hurricane" at 8 p.m., October 1, 1866 and the probable path of the storm. (After Buchan.)**

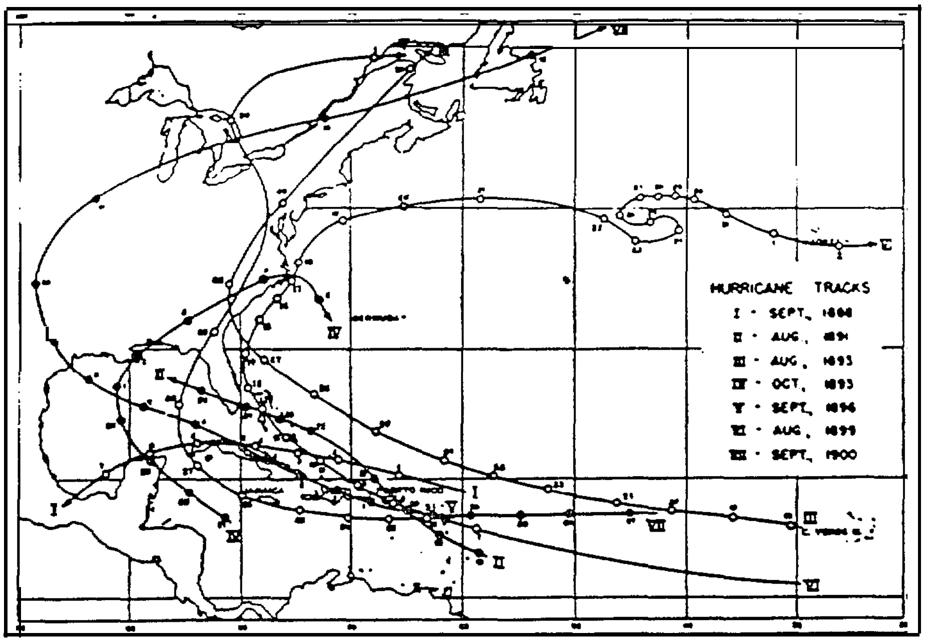

FIGURE F-15. **Tracks of principal West Indian hurricanes, 1888 to** 1900.

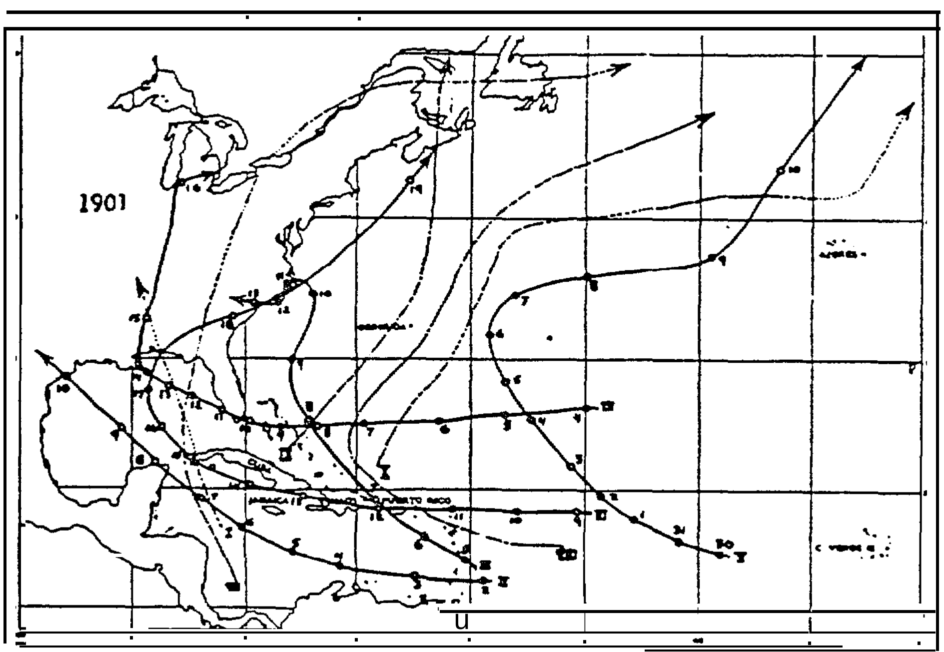

FIGURE F-16. **Tracks of tropical storms of 1901. i. June 10 to 13; II. July 2 to 10; III. July 5 to 13; IV. August 4 to 16; V. August 30 to September 10; VI. September 9 to 19; Vii. September 20 to 30; VIII. October 7 to 14; IX. October 16 to 18; and X. October 31 to November 10.**

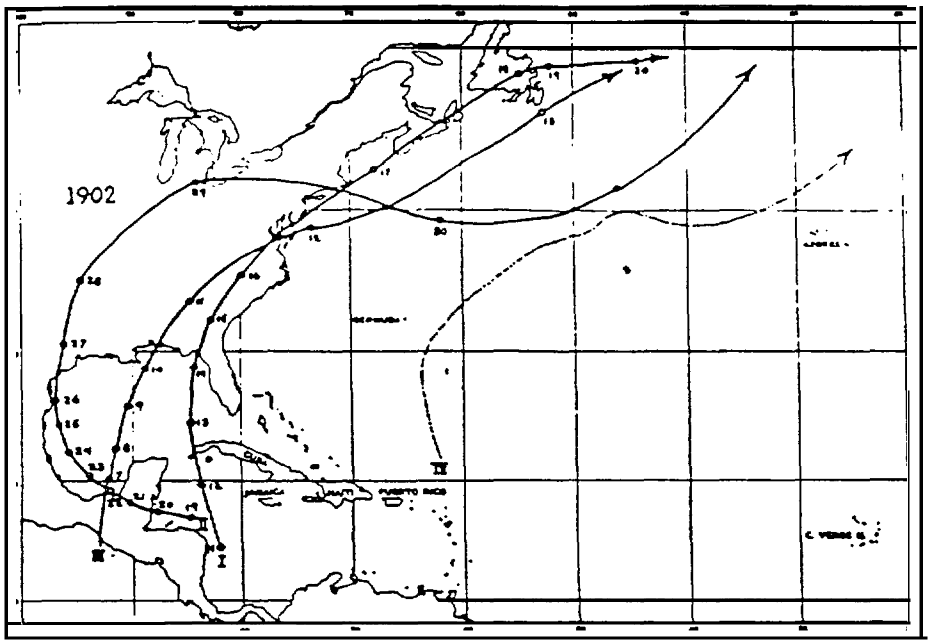

FIGURE F-17, Tracks of tropical storms of 1902. I. June 11 to 20; II. June 19 to July 1; III. October 7 to 13; IV. November 1 to 9.

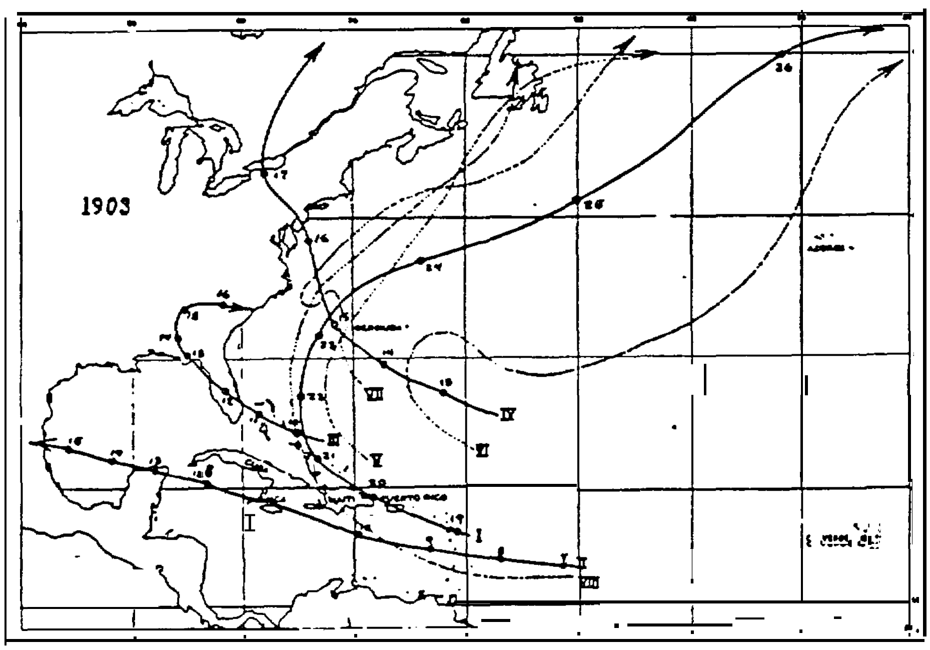

FIGURE F-18. Tropical storm tracks of 1902. I. July 19 to 26; II. August 7 to 15; III. September 10 to 16; IV. September 13 to 17; V. September 22 to 25; VI. October 1 to 10; VII. October 7 to 14; VIII. October 18 to 27.

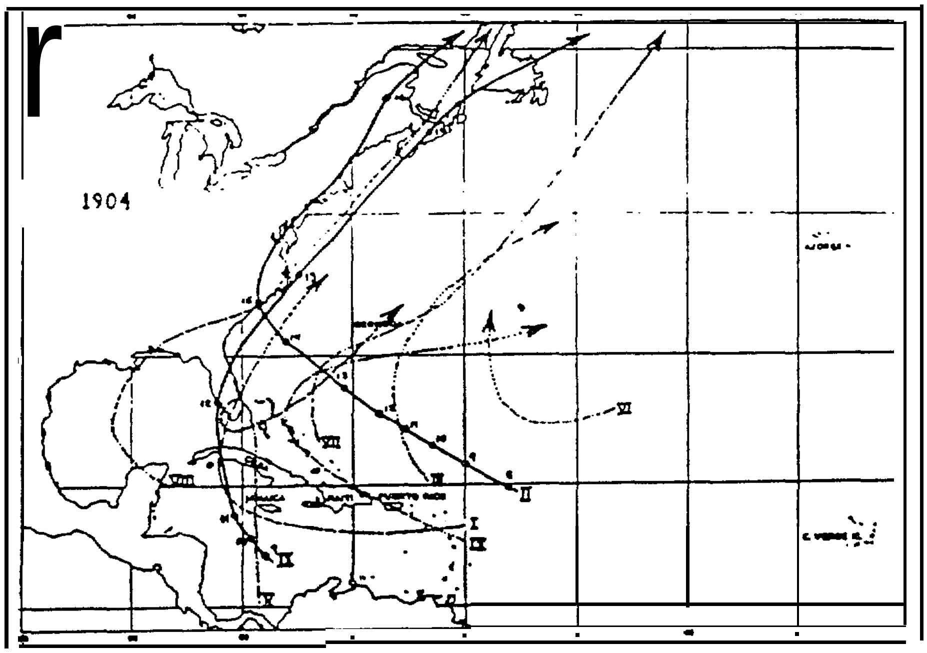

FIGURE F-19. Tracks of tropical storms of 1904. I. September 3 to 9; II. September 8 to 16; III. September 24 to 30; IV. October 10 to 16; V. October 10 to 23; VI. October 19 to 23: VII. October 28 to November 2: VIII. October 29 to November 6; IX. November 9 to 14.

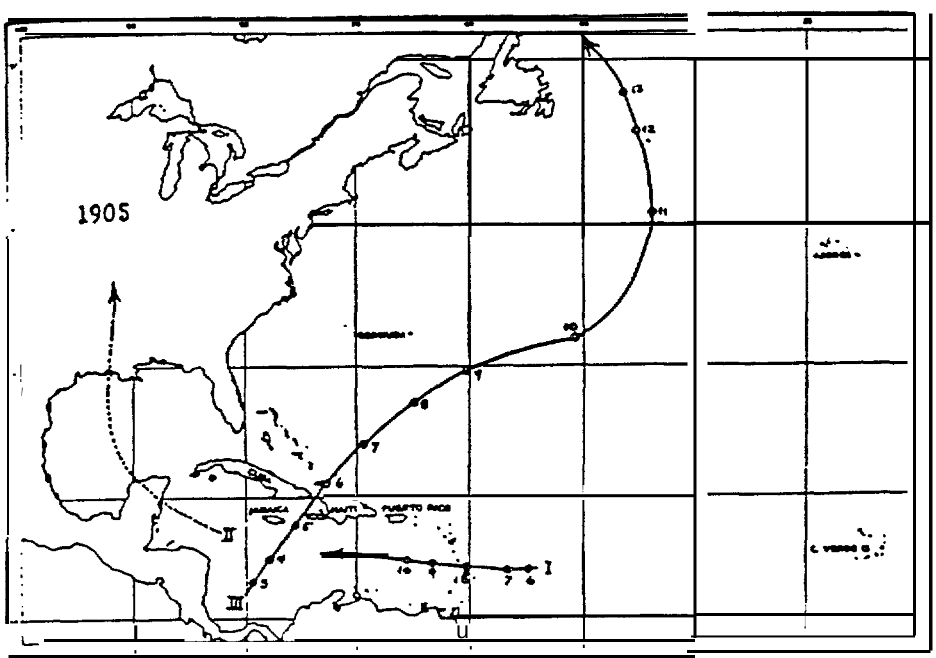

FIGURE F-20. Tracks of tropical storms of 1905. L September 6 to 10; II. September 24 to 30; III. October 3 to 13.

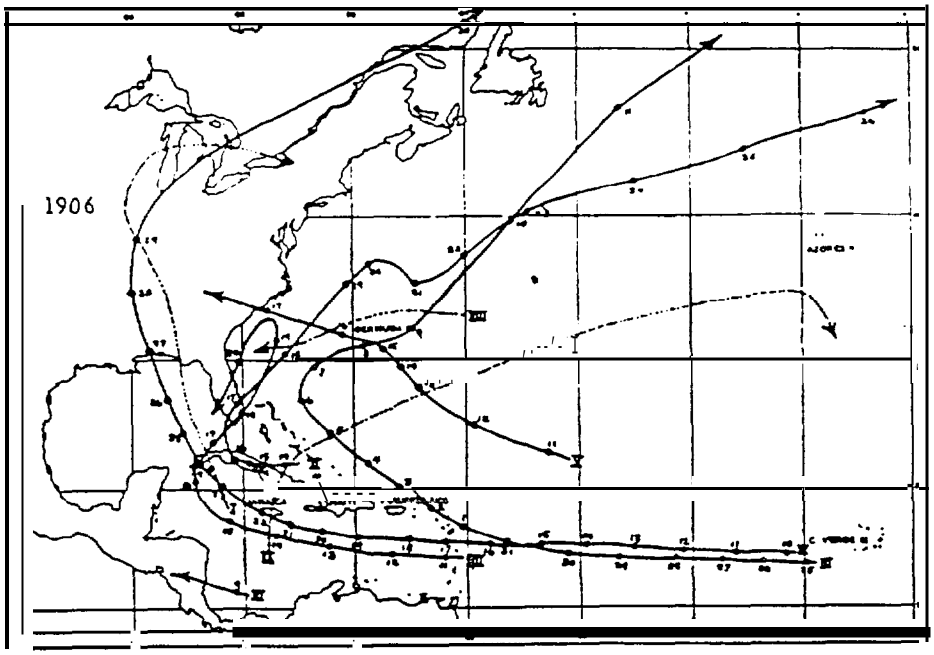

FIGURE F-21. Tracks of tropical storms of 1906. L June 8 to 16; II. June 14 to 26; III. August 25 to September 11; IV. September 10 to 30; V. September 11 to 17; V1. October 9: VII. October 11 to 20; VIII. October 13 to 17; ix. N-ovember 6 to 13.

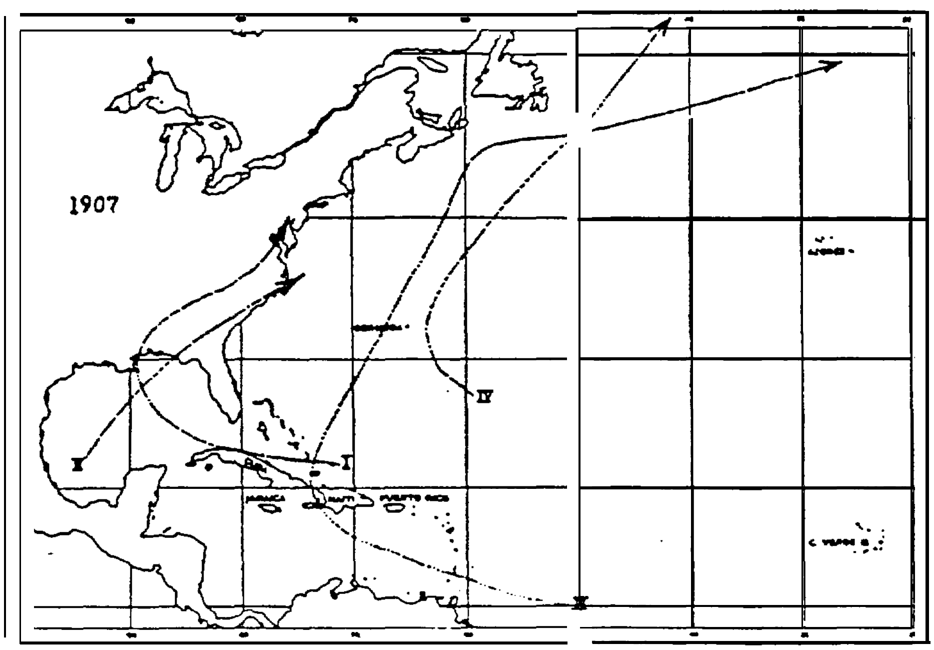

FIGURE F-22. Tracks of tropical storms of 1907. 1. September 16 to 23: II. September 27 to 29; III. October 3 to 17; Iv. October 17 to 20.

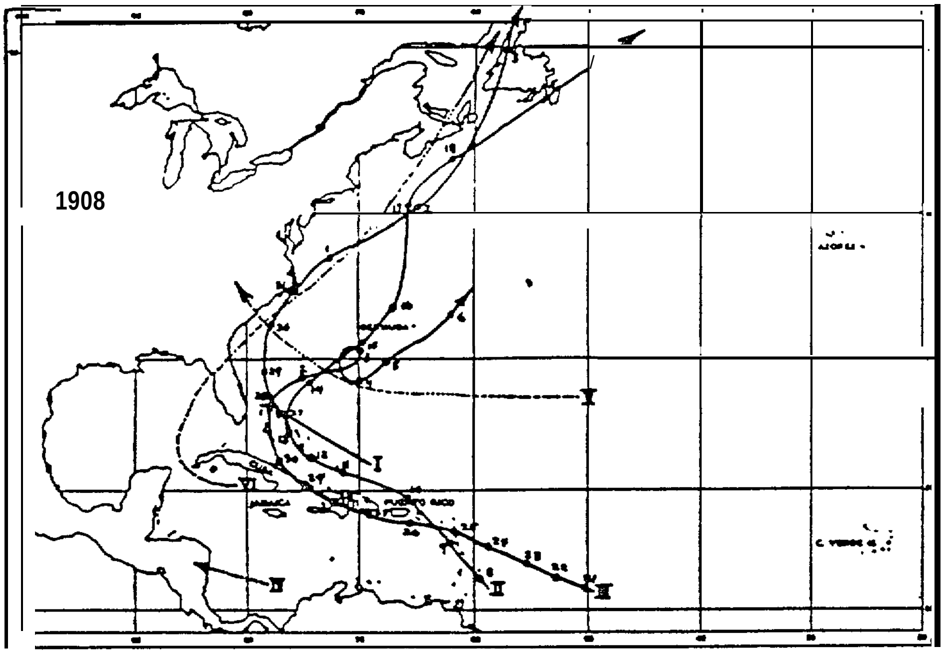

FIGURE F-23. Tracks of tropical storms of 1908. L July 27 to August 4; IL September 8 to 18; III. September 21 to October 6; W. 'October 17; V. October 18 to 23; VI. October 25 to 31.

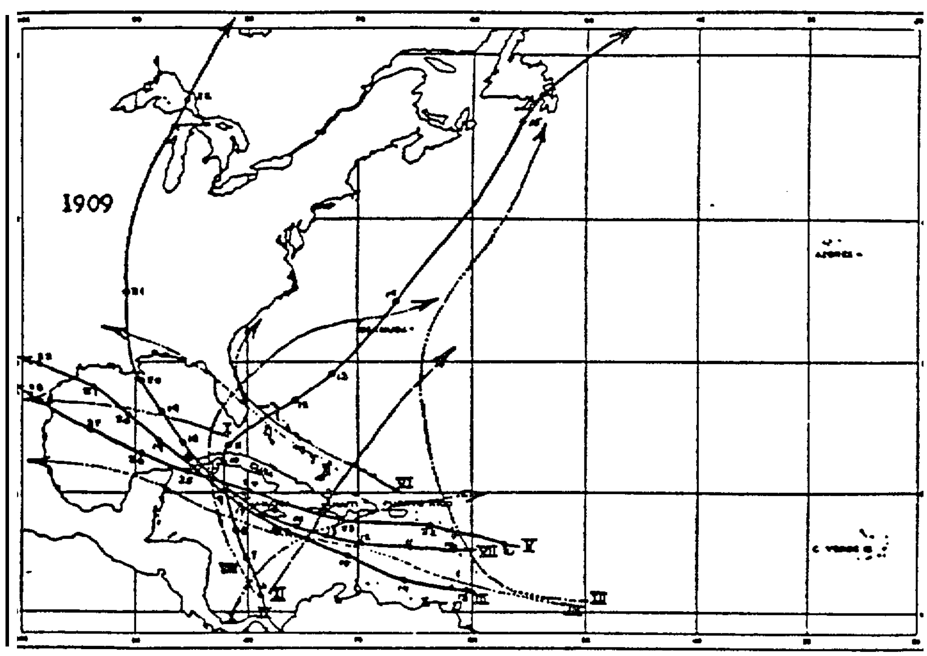

FIGURE F-24. Tracks of tropics! storms of 1909. 1. June 25 to 30; II. June 26 to July 1; III. July 13 to 22; W. July 27 to August 10; V. August 21 to 28; VI. August 27 to 31; Vii. September 10 to 22; VIII. September 22 to 30; IX. October 6 to 15; X. November 8 to 14; XI. November 22 to 25; Xii. November 25 to December 2.

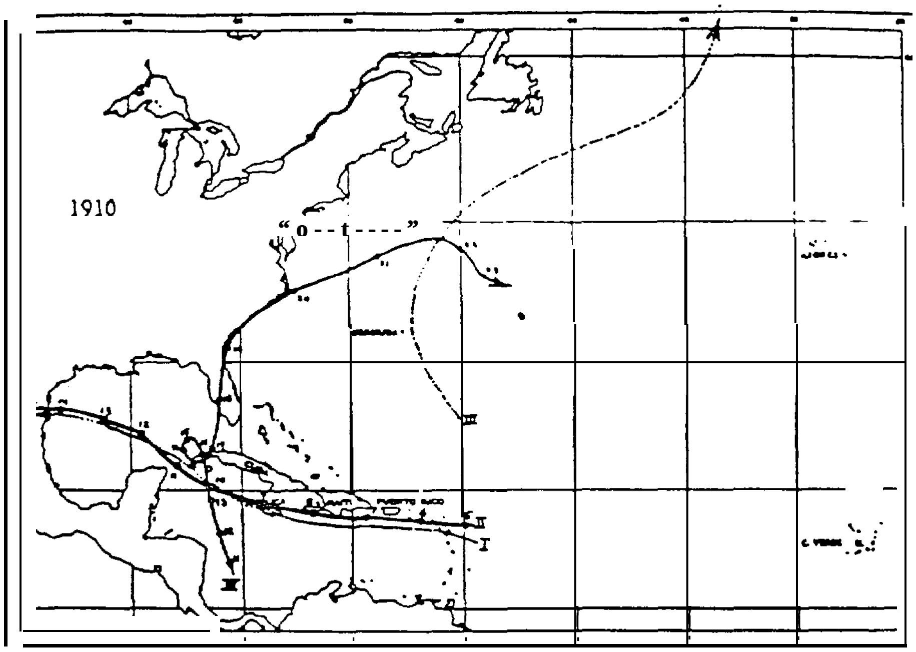

FIGURE F-25. Tracks of tropical storms of 1910. L August 23 to 31; II. September 5 to 14; III, September 23 to October 1; IV. October 11 to 23.

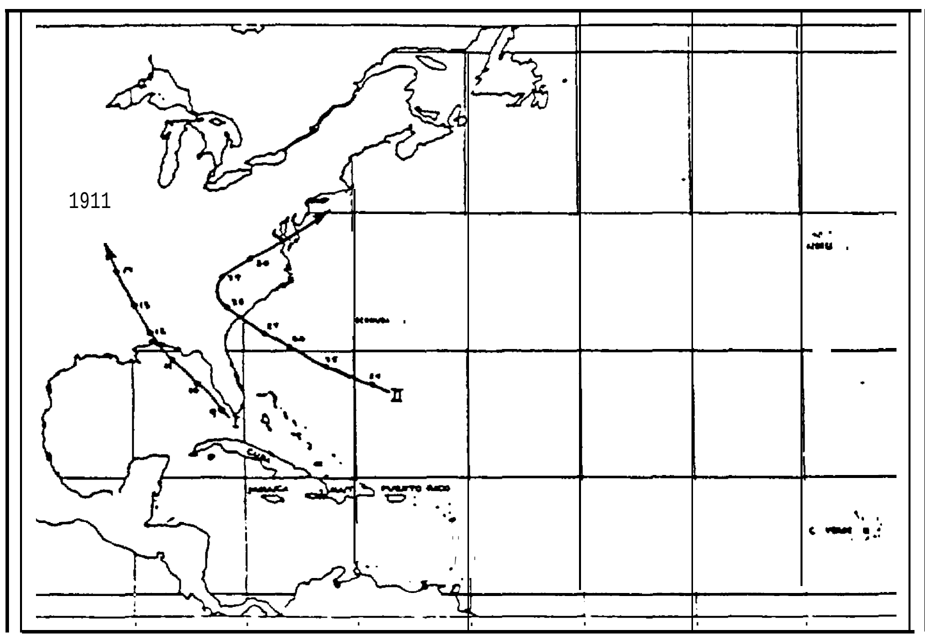

FIGURE F-26. Tropical storm tracks of 1911. 1. August 9 to 14; II. August 24 to 30.

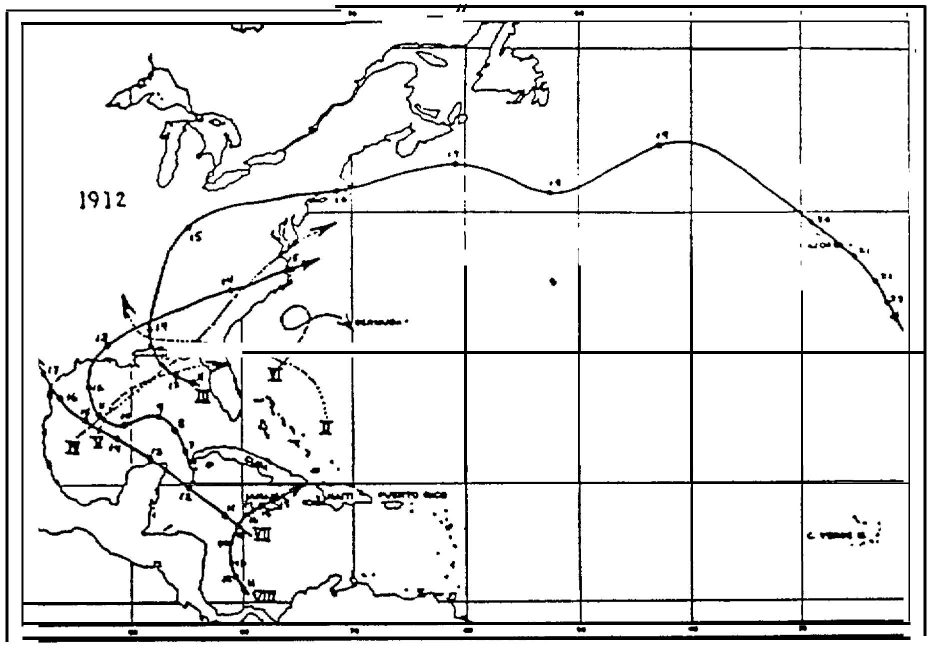

FIGURE F-27. Tracks of tropical storms of 1912. L June 7 to 15; II. July 12 to 17; III. September 11 to 23; IV. September 21 to 25; V. October 2 to 4; VI. October 4 to 9; VII. October 11 to 17; VIII. November 11 to 19.

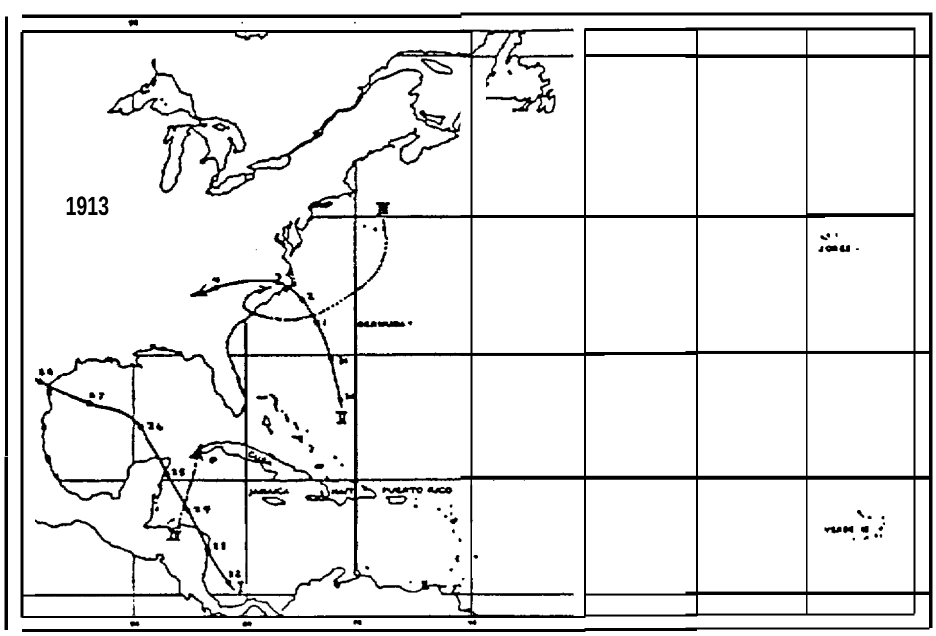

FIGURE F-28. Tracks of tropical storms of 1913. 1. June 22 to 28; II. August 30 to September 4; III. October 3 to 9: IV. October 27 to 29.

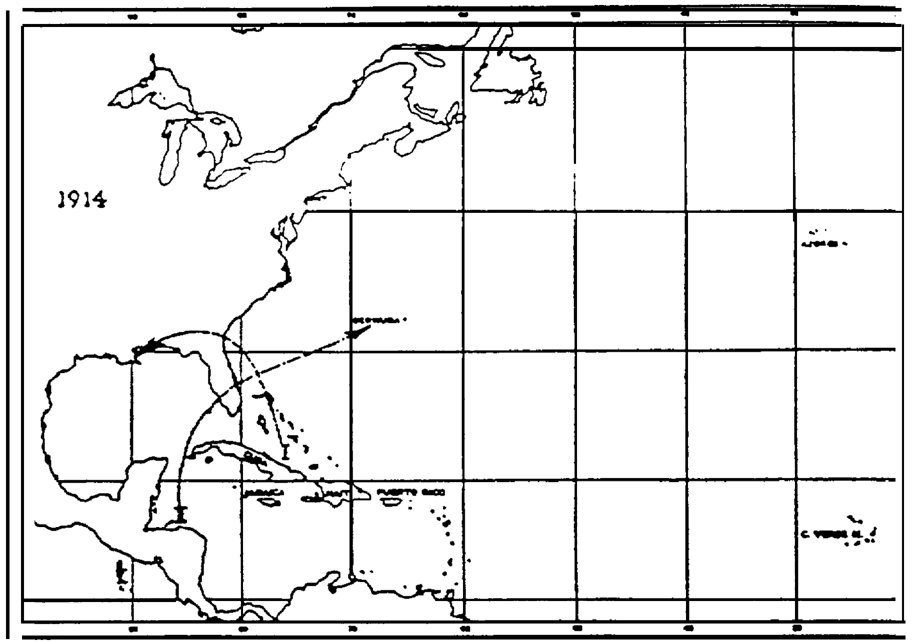

FIGURE F-29. Tracks of tropical storms of 1914. 1. September 14 to 18: II. October 24 to 27.

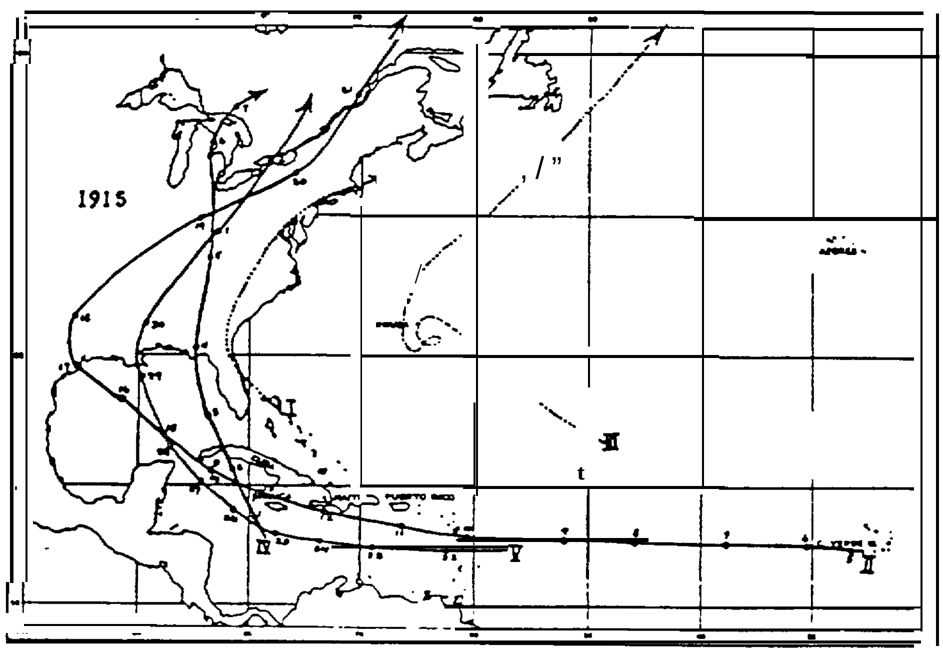

FIGURE F-30. Tracks of tropical storms of 1915. 1. July 31 to August 5; II. August 5 to 24; III. August 28 to September 13; IV. September 1 to 7; V. September 22 to October 2.

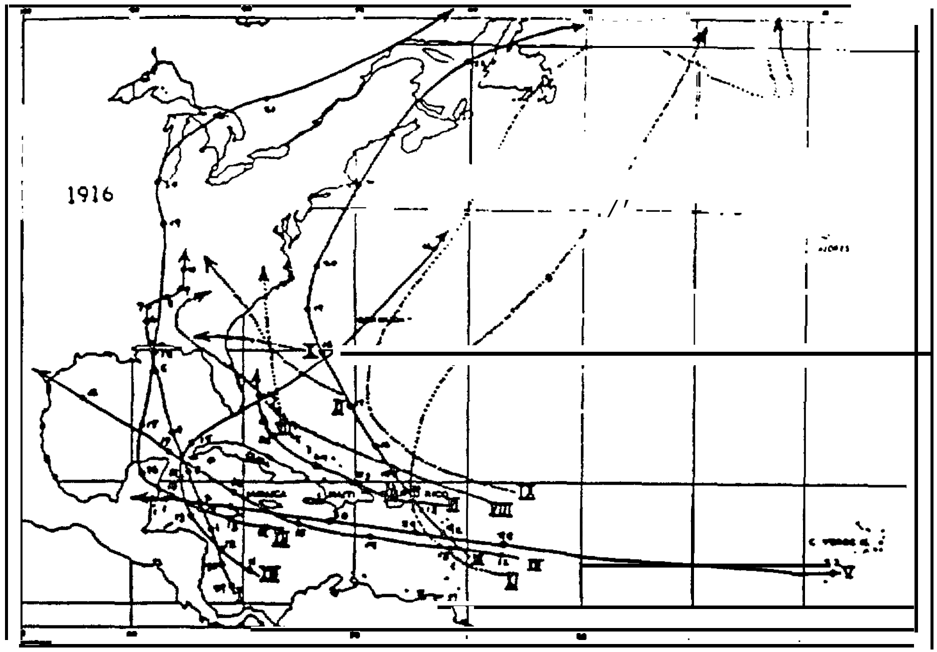

FIGURE F-31. Tracks of tropical storms of 1916. L June 29 to July 10; II. July 11 to 15; III. July 12 to 22; IV. August 12 to 18; V. August 22 to September 1; VI. August 22 to 25; VII. September 4 to 7; VIII. September 9 to 14; IX. September 21 to October 2; X. October 3 to 5; XI. October 6 to 14; X11. October 12 to 21; XIII. November 11 to 16.

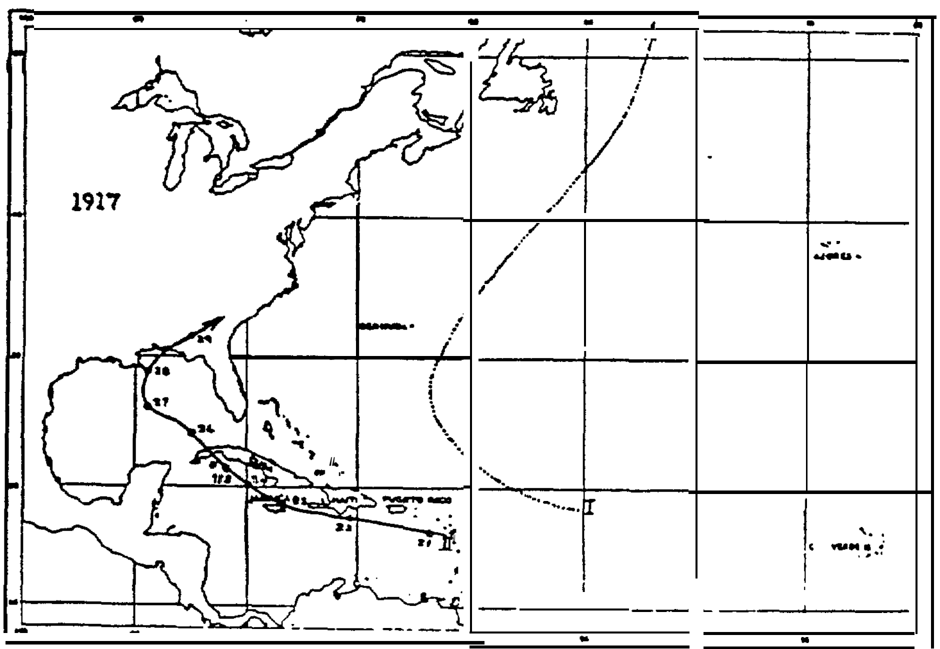

FIGURE F-32. Tracks of tropical storms of 1917. L August 31 to September 6; II. September 21 to 29.

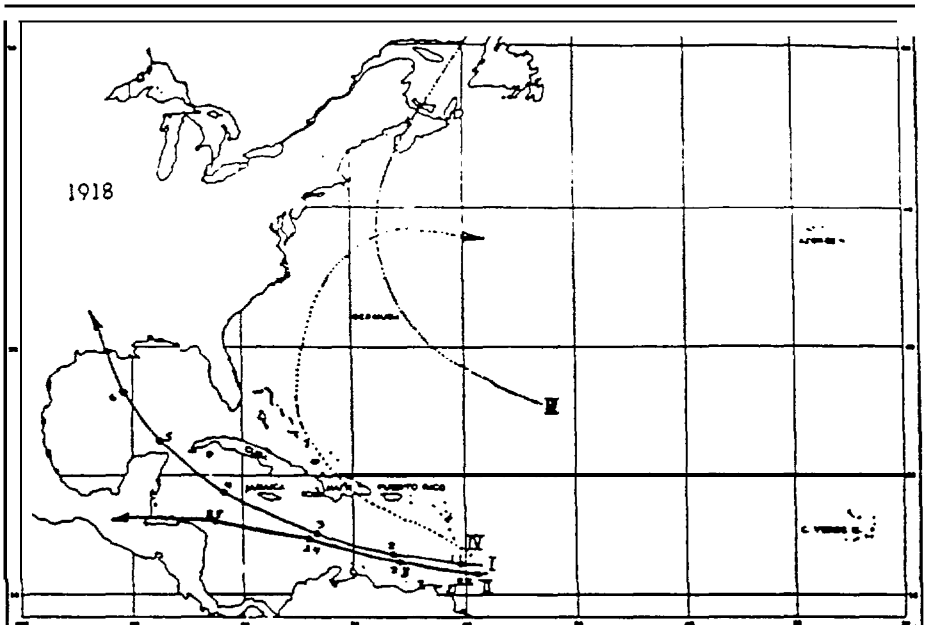

FIGURE F-33. Tropical storm tracks, 1918. I. August 1 to 6; II. August 21 to 25; III. September 4 to 8; IV. September 9 to 16.

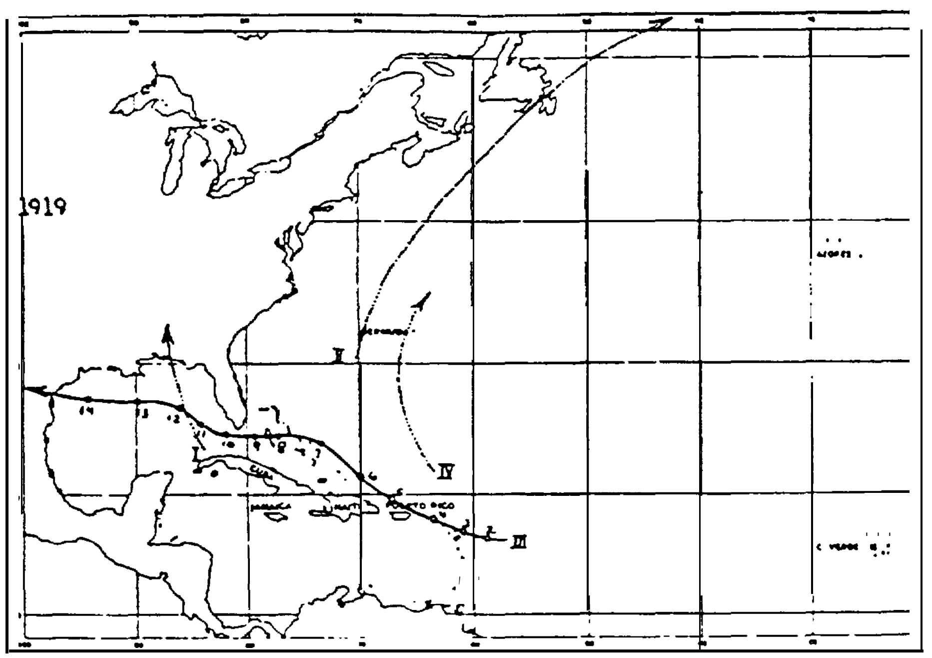

FIGURE F-34. Tracks of tropical storms of 1919. I. July 2 to 4; II. September 1 to 4; III. September 2 to 14; IV. November 11 to 14.

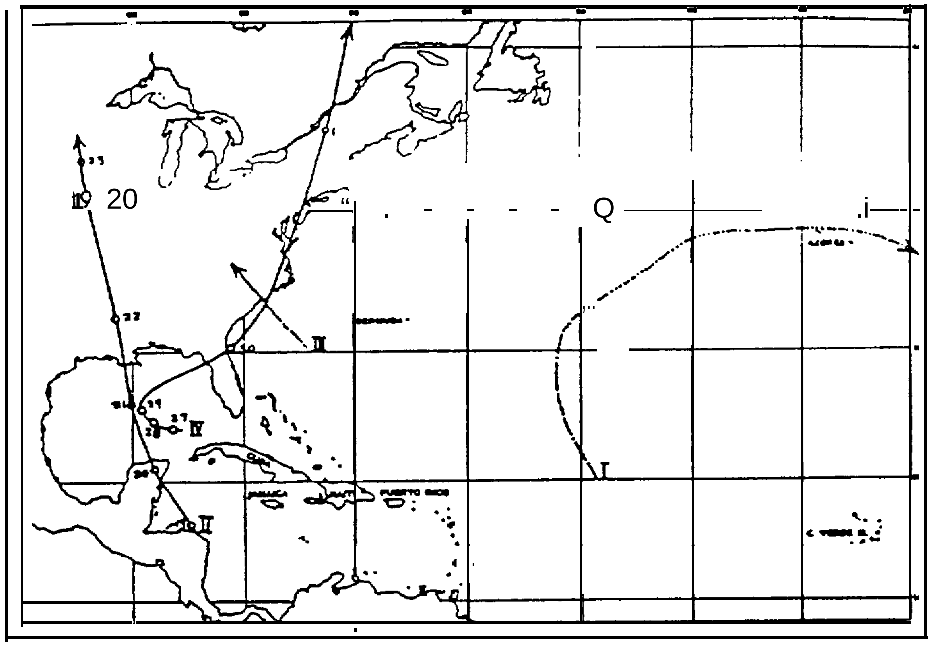

FIGURE F-35. Tracks of tropical storms of 1920. L September 10 to 18; II. September 19 to 23; III. September 22 to 23; IV. September 27 to October 1.

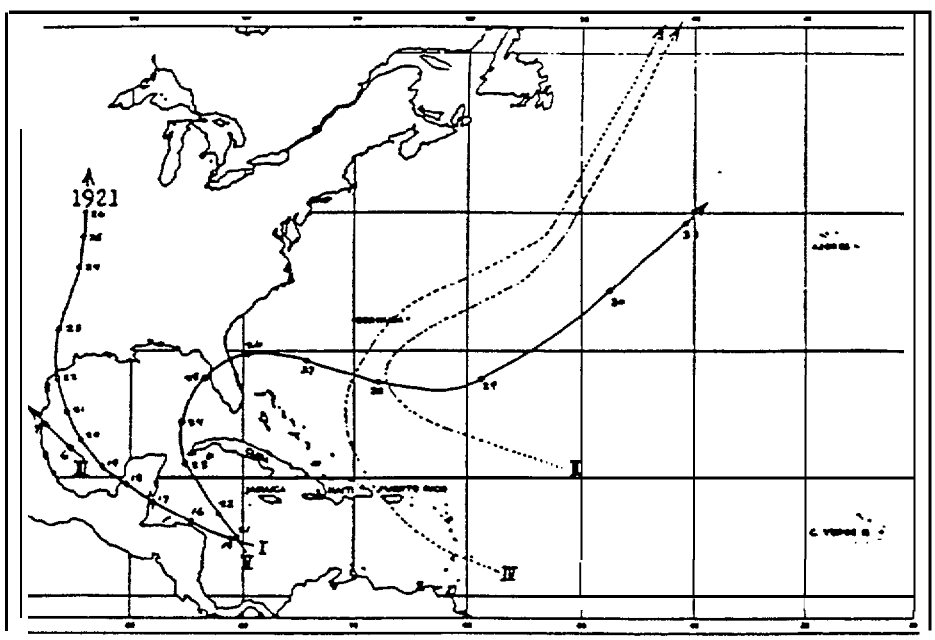

FIGURE F-36. Tracks of tropical storms of 1921. 1. June 15 to 26; II. September 5 to 14; III. September 6 to 7: IV. September 8 to 17'; V. October' 21 to 31. '

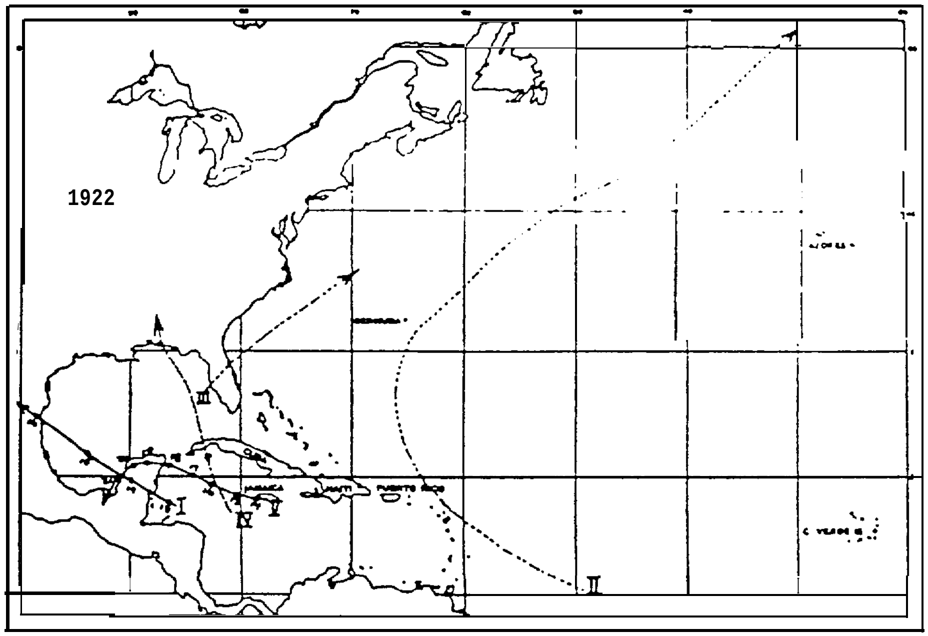

FIGURE F-37. Tracks of tropical storms of 1922. 1. June 13 to 16: II. September 13 to 24: III. September 17 to 22: IV. October 12 to 17; V. October 14 "to 21.

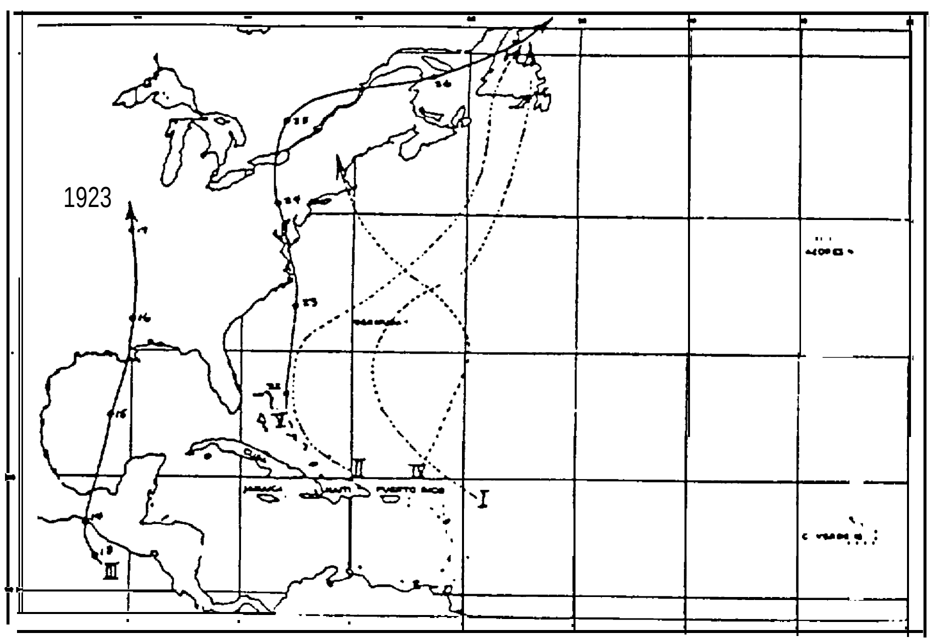

FIGURE F-38. Tracks of tropical storms of 1923. I. August 29 to September 10; II. September 24 to October 2; III. October 13 to 17; IV. October 14 to 19; V. October 22 to 26.

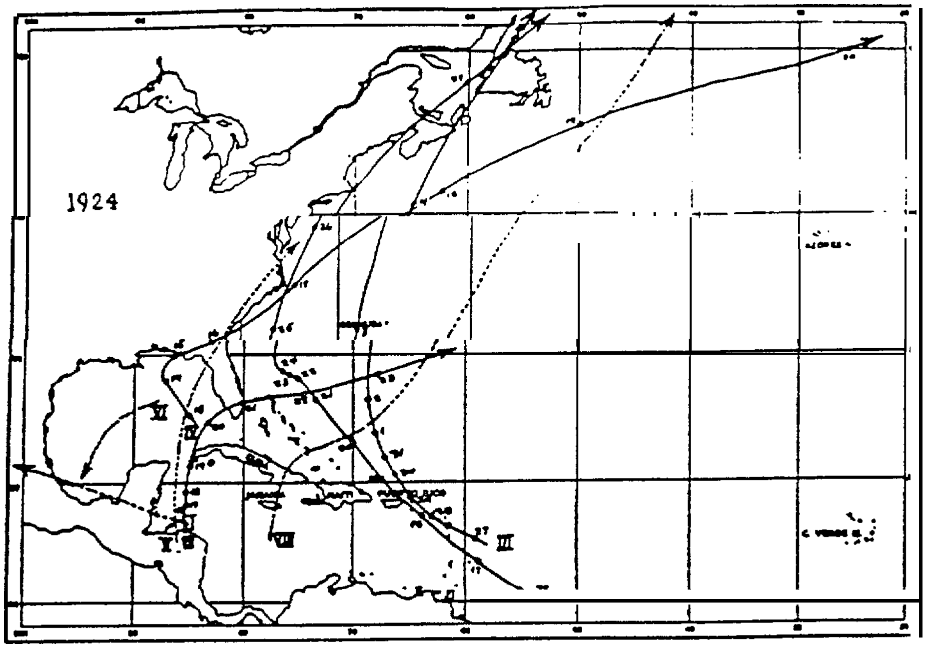

FIGURE F-39. Tracks of tropical storms of 1924. L June 18 to 21; II. August 16 to 27; III. August 27 to September 5; IV. September 13 to 20; V. September 27 to 30; VI. October 12 to 14; VII. October 16 to 23; VIII. November 7 to 15.

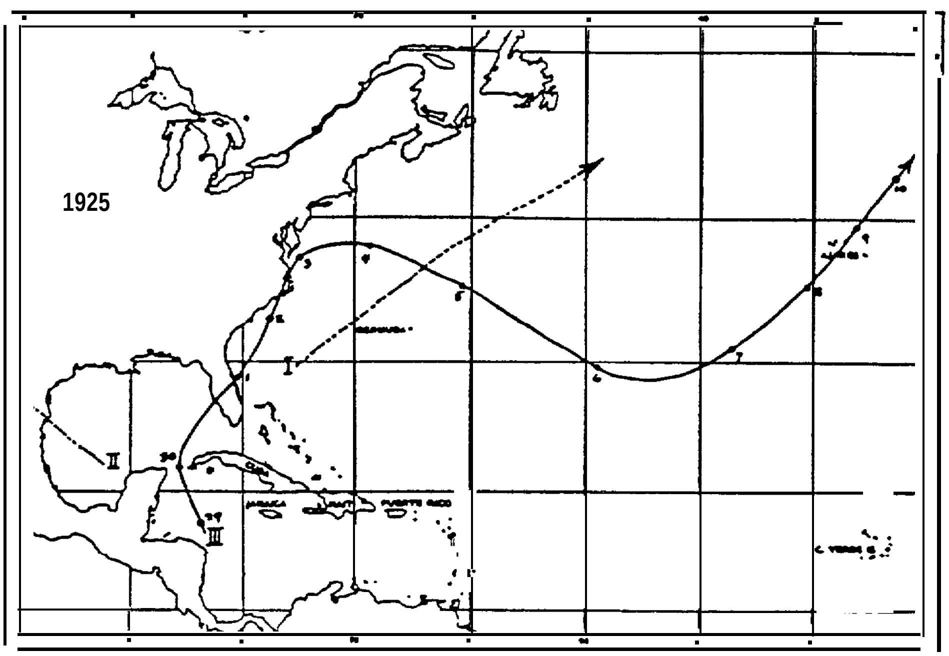

FIGURE F-40. Tracks of tropical storms of 1925. L August 18 to 21; II. September 6 to 7; III. November 29 to December 10.

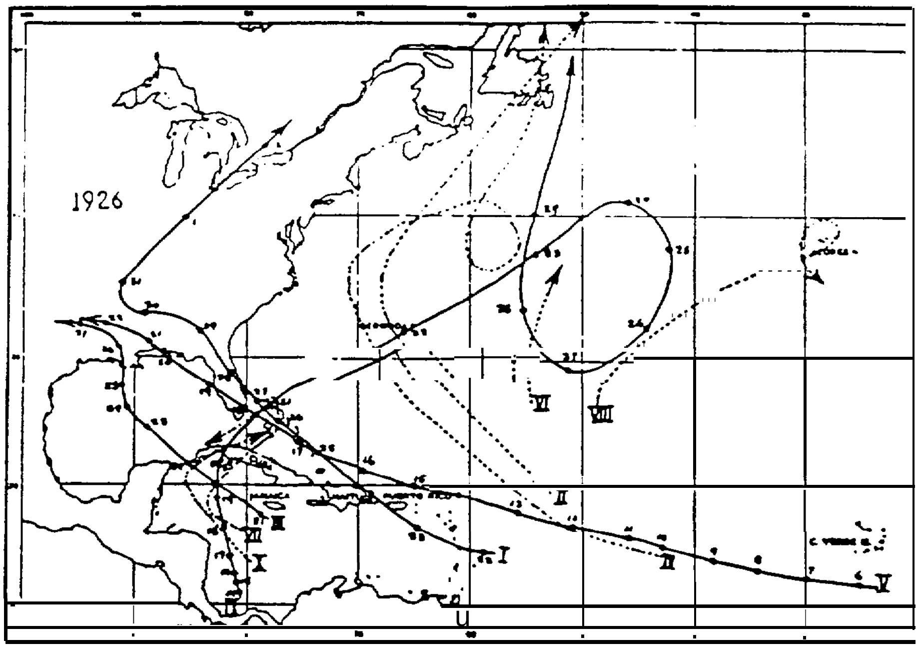

FIGURE F-41. Tracks of tropical storms of 1926. 1. July 22 to August 2; II. ' August 1 to 9; III. August 21 to 27; W. September 2 to 23; V. September 6 to 22; VI. September 11 to 14; VII. "September 11 to 17; VIII. September 22 to 29; IX. October 14 to 29; X. November 13 to 16.

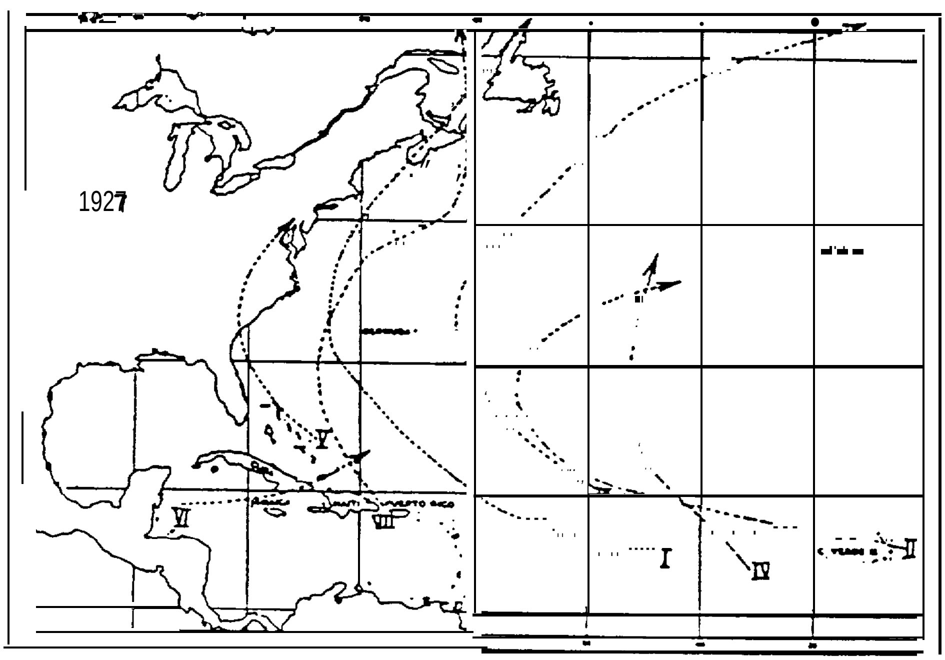

FIGURE F-42. Tracks of tropical storms of 1927. L August 19 to 27; II. September 3 to 11; III. September 23 to 30; IV. September 25 to 29; V. October 1 to 3; Vi. October 17 to 19; VII. November 1 to 6.

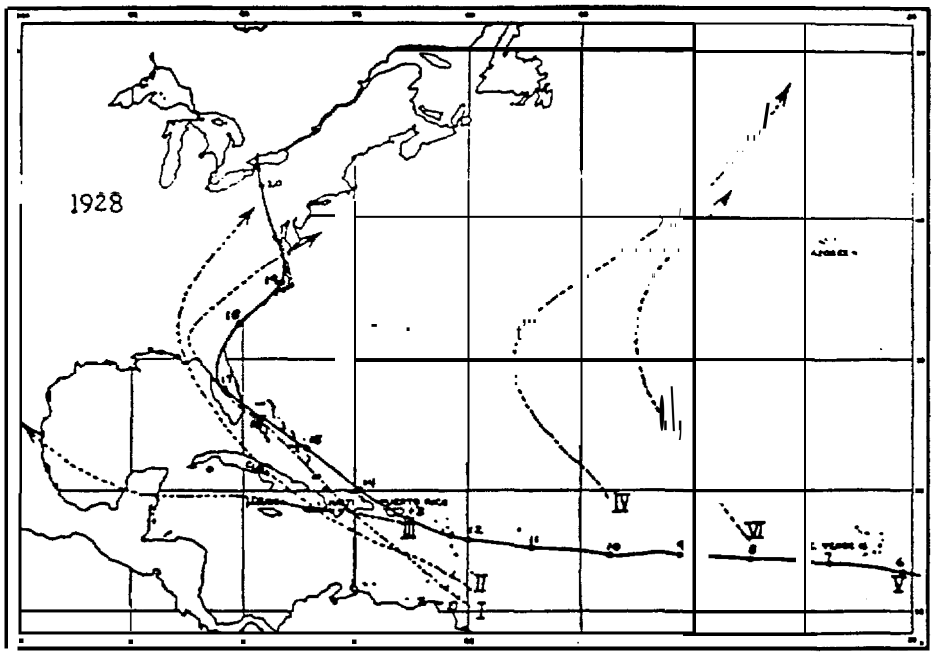

FIGURE F-43 . **Tracks of tropical storms of 1928. L August 3 to 12; II. August 7 to 17; III. September 1 to 7; IV. September 8 to 12; V. September 6 to 20; VI. October 10 to 14.**

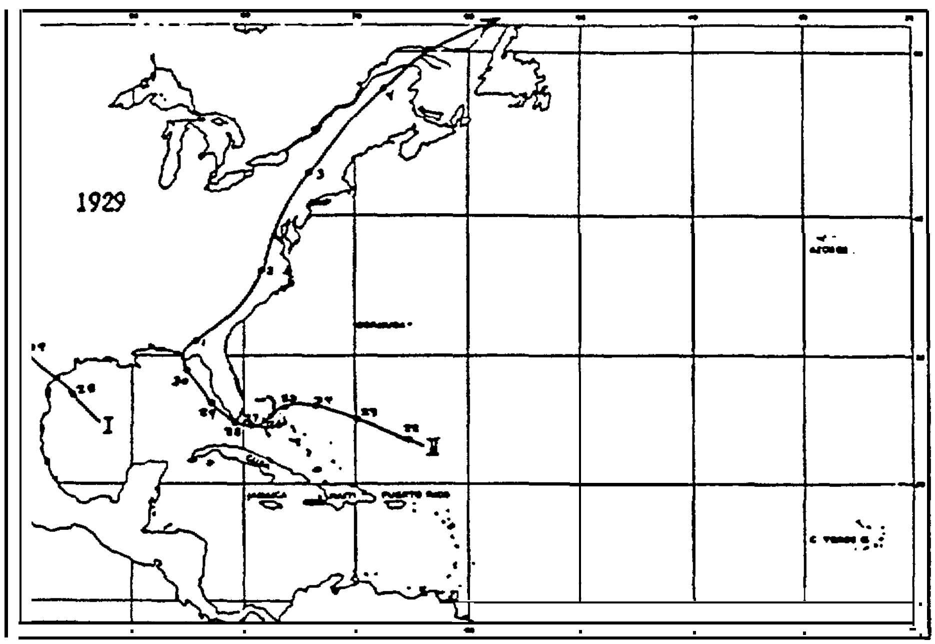

FIGURE F-44. **Tracks of tropical storms of 1929. 1. June 28 to 29; II. September 22 to October 4.**

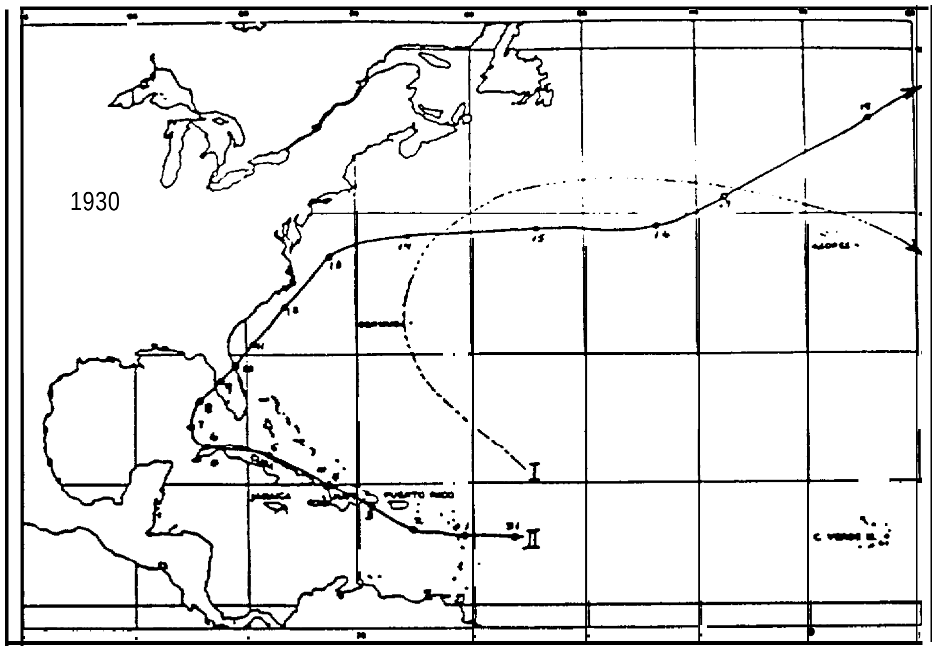

FIGURE F-45. Tracks of tropical storms of 1930. L August 22 to 31; Ii. August 31 to September 18.

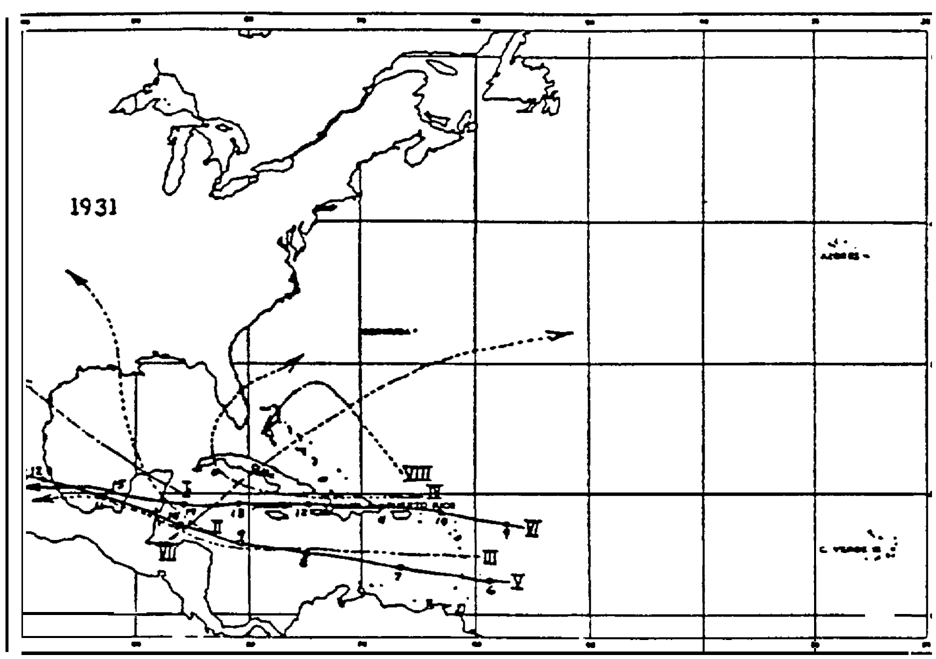

FIGURE F-46. Tracks of tropical storms of 1931. i. June 25 to 28: II. Juiy 11 to 15; iii. August 10 to 18; IV. September 2 to 9; V. September 6 to 12; VI. September 9 to 15; Vii. October 18 to 21; VIII. November 22 to 25.

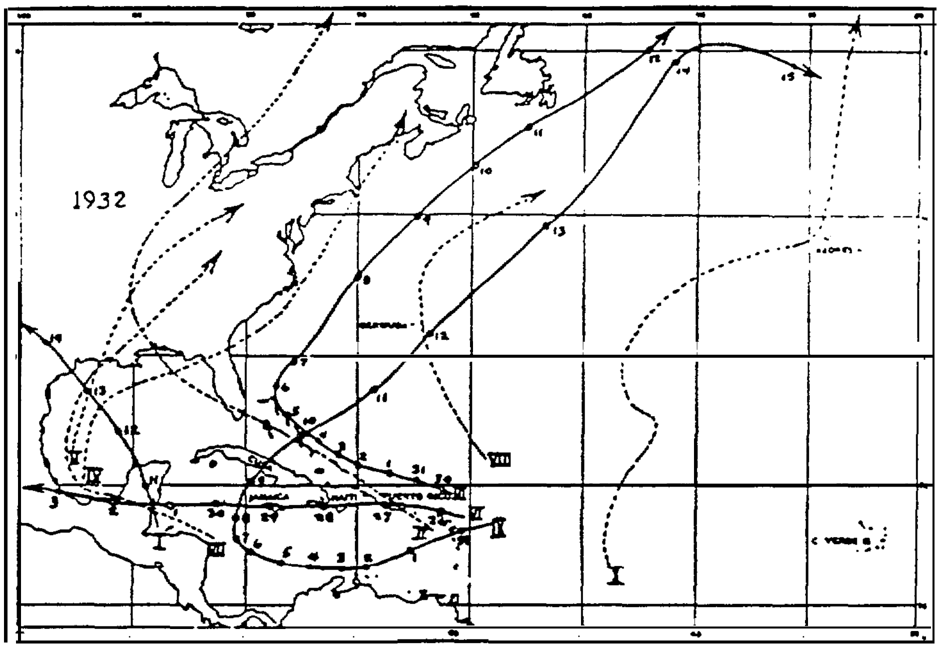

FIGURE F-47. **Tracks of tropical storms of 1932. I. August 11 to 14; II. August 24 to September 4; III. August 30 to September 12; IV. September 9 to 17; V. September 18 to 21: VI. September 26 to October 3: VII. October 7 to 17; "VIII. Ott'ober 9 to 12; IX. October 31 to November 15; X. November 3 to 11.**

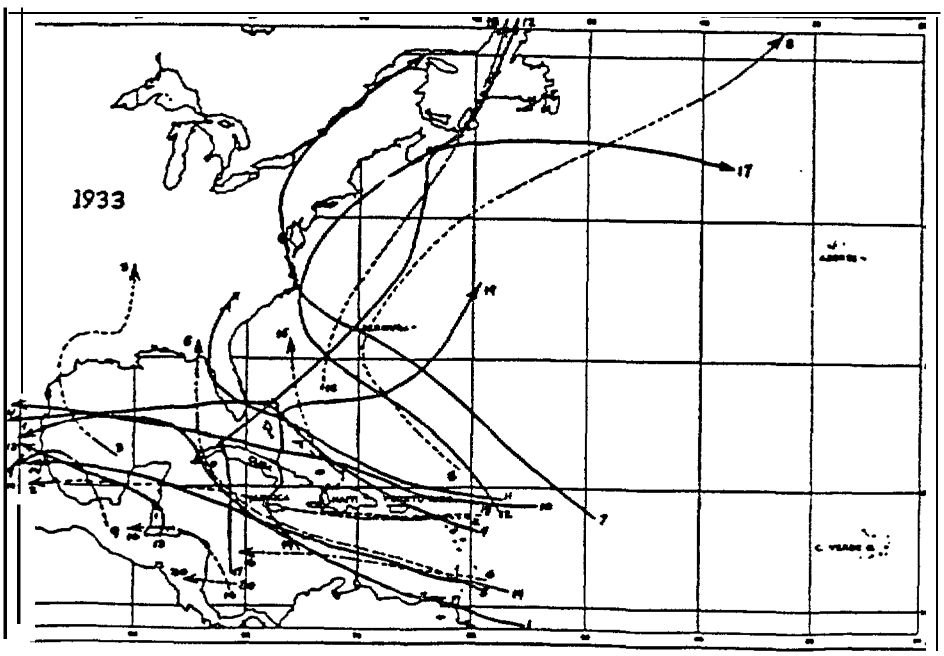

FIGURE F-48, Tracks of tropical storms of 1933.

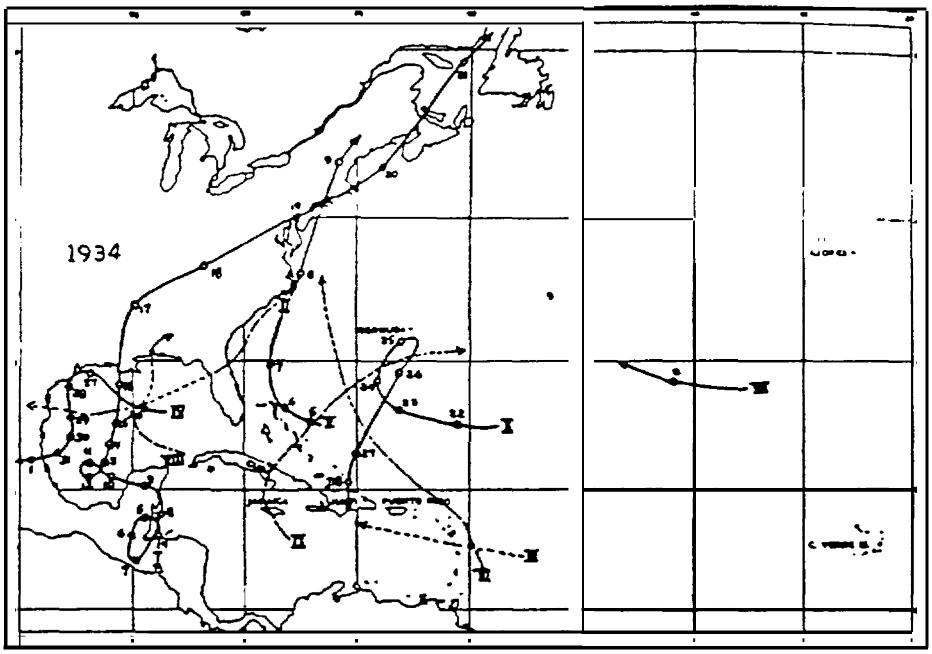

FIGURE F-49, Tracks of tropical storms of 1934. 1. June 4 to 21; II. July 21 to 25; III. August 20 to 22; IV. August 26 . to September 1; V. September 5 to 9; Vi. September 15 to 21; VII. October 1 to 2; VIII. October 3 to 5; IX. October 19 to 23; X. November 21 to 28.

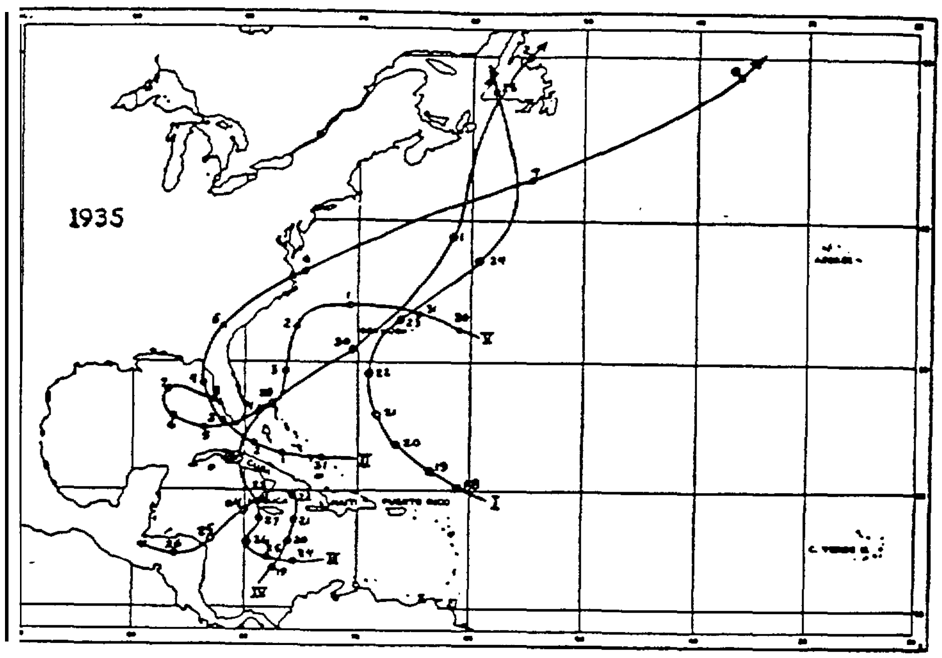

FIGURE F-sO. Tracks of tropical storms of 1935. L August 18 to 25; II. August 31 to September 8; III. September 23 to October 2; IV. October 19 to 26; V. October 30 to November 8.

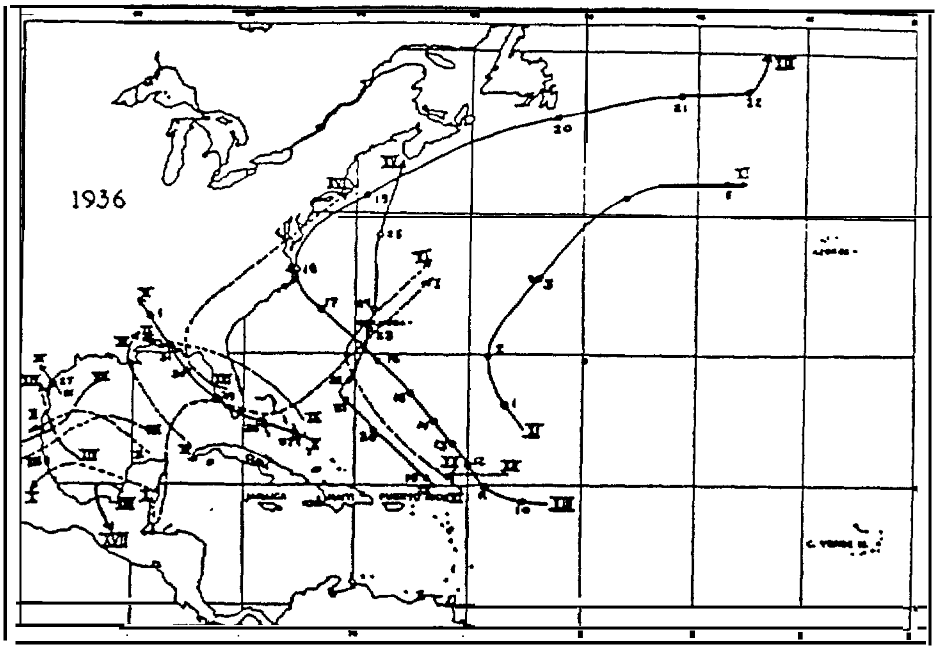

FIGURE F-51. **Tracks of tropical storms of 1936.**

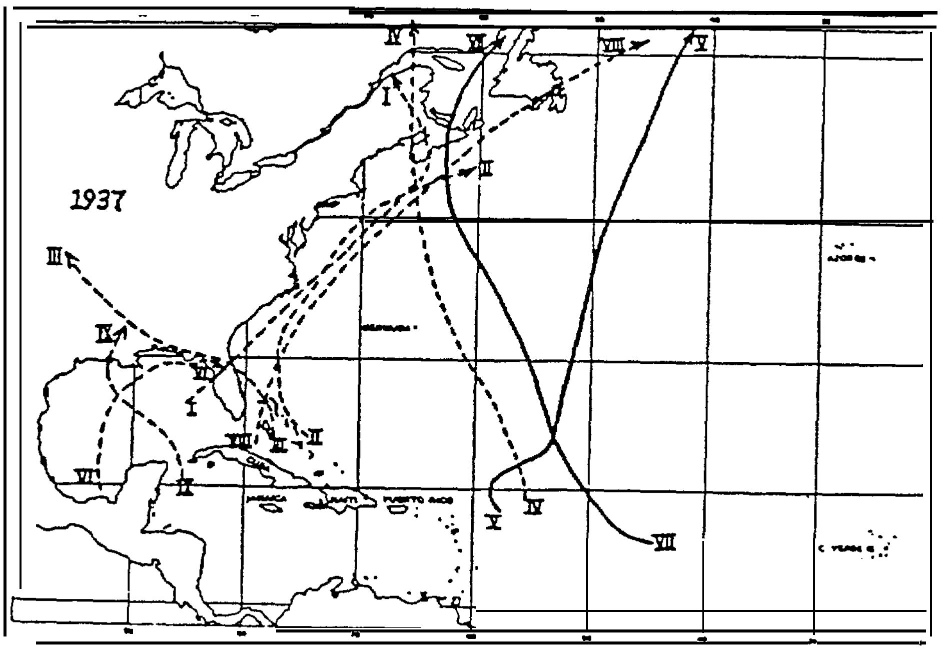

FIGURE F-52. **Tracks of tropical storms of 1937. 1. July 29 to August 2; II. August 2 to 8; III. August 28 to September 2; IV. September 9 to 14; V. September 14 to 20; VI. September 16 to 21; Vii. September 20 to 26; VIII. September 26 to 30; IX. September 30 to October 2.**

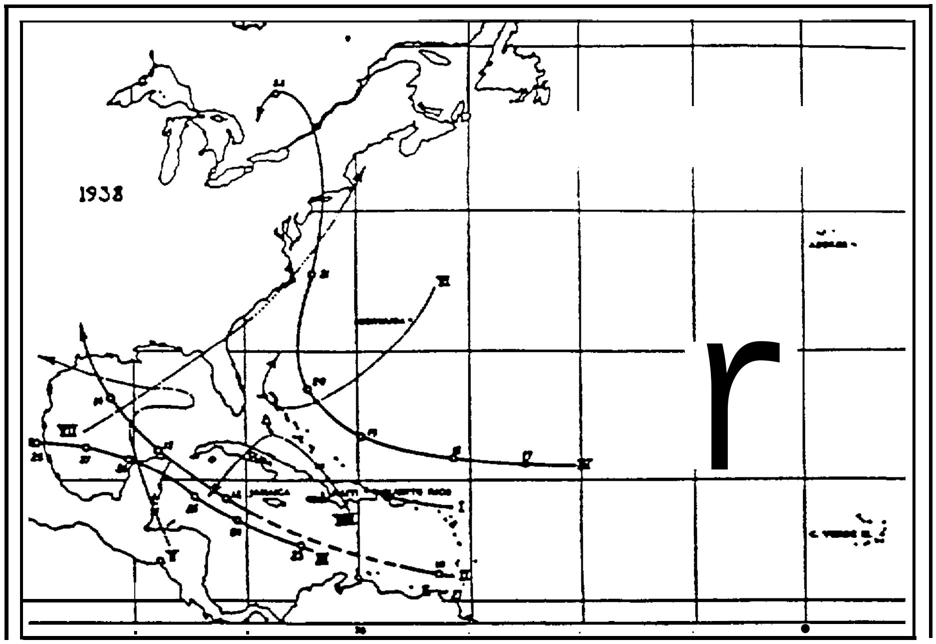

FIGURE F-53. **Tracks of tropical storms of 1938. 1. August 8 to 10; II. August 9 to 14; III. August 23 to 28; IV.**

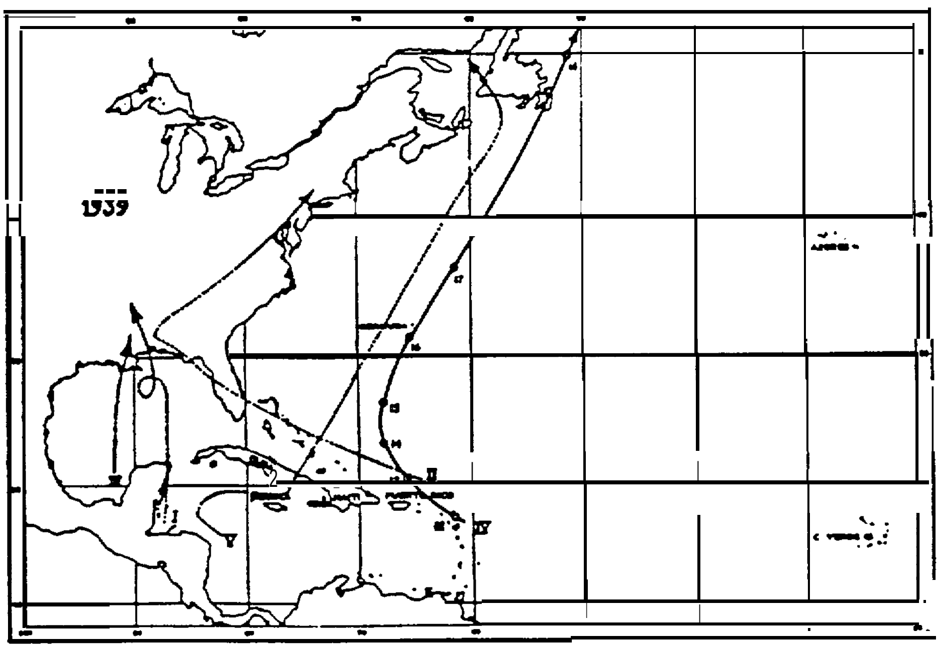

FIGURE F-54. Tracks of tropical storms of 1939. 1. June **12 to 16; II. August 8 to 20; III. September 24 to 26; IV. October 12 to 18; V. October 29 to November 8.**

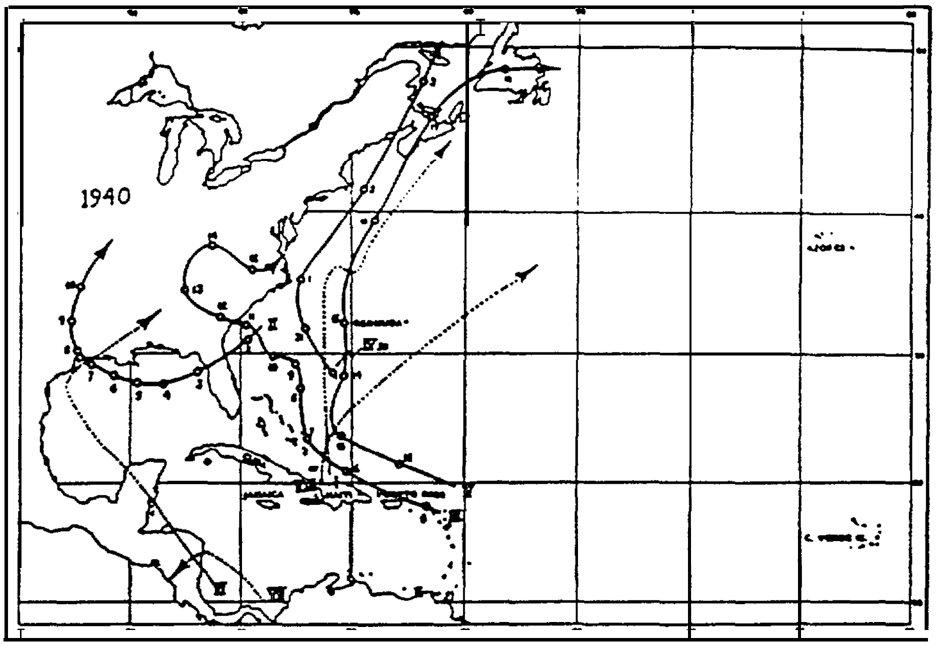

FIGURE F-55. Tracks of tropical storms of 1940. 1. May 18 to 27: II. August 2 to 10; III. August 5 to 15; IV. August'30 to September 3; V. September 11 to 18; VI. September 19 to 24; VII. October 20 to 23; VIII. October 24 to 26.

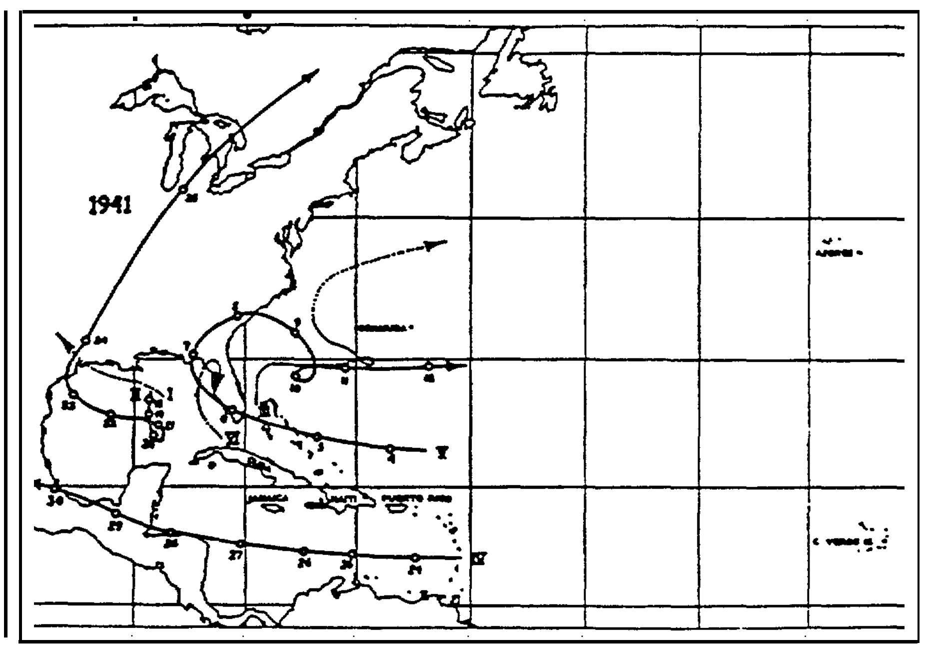

FIGURE F-56. Tracks of tropical storms of 1941. 1. September 11 to 14; II. September 18 to 25; III. September 18 to 26; IV. September 24 to 30; V. October 4 to 12; VI. October 19 to 21.

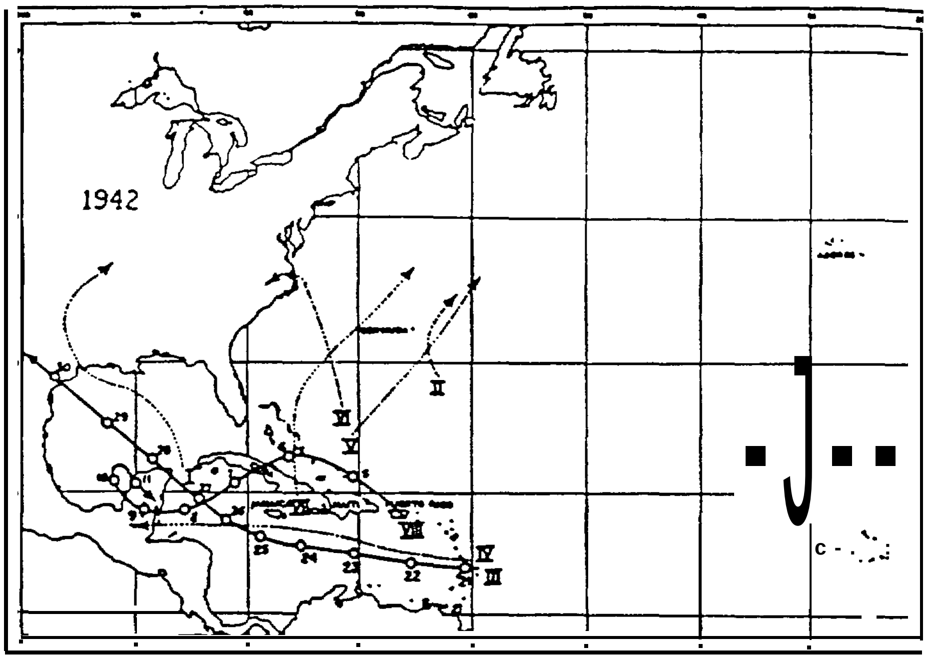

FIGURE F-57. Tracks of tropical storms of 1942. 1. August 18 to 22: II. August 25 to 26; III. August 21 to 30: IV. September 15 to 22; V. October 1 to 3; VI. October 10 to 12; VII. October 13 to 18; VIII. November 5 to 11.

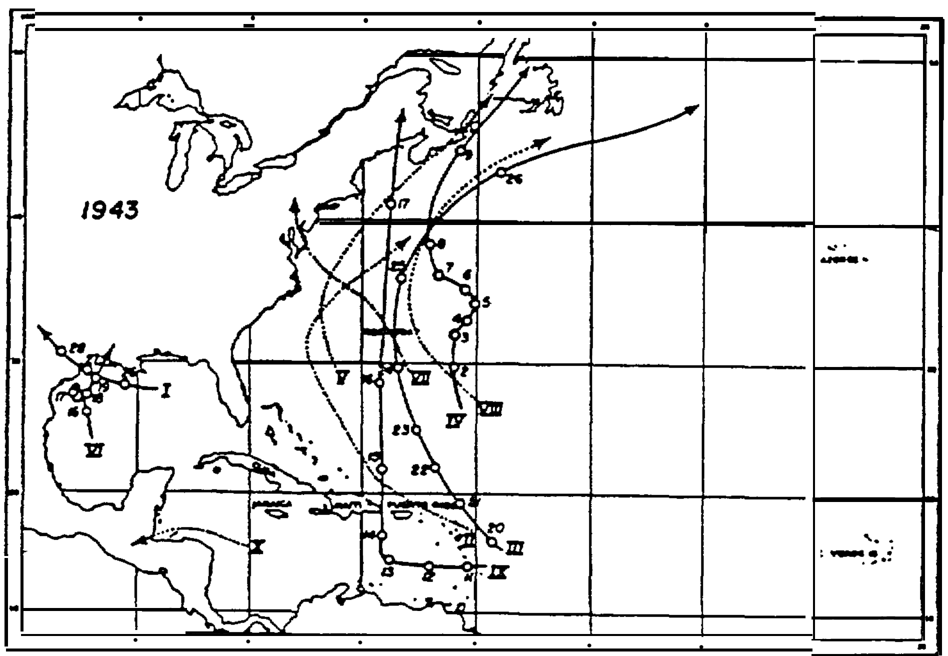

FIGURE F-58. Tracks of tropical storms of 1943. L July 26 to 28: II. August 13 to 19; III. August 20 to 27; IV. September 1 to 9; V. September 13 to 16; V1. September 16 to 19; VII. September 28 to October 1; VIII. October 1 to 3; IX. October 11 to 17; X. October 21 to 22.

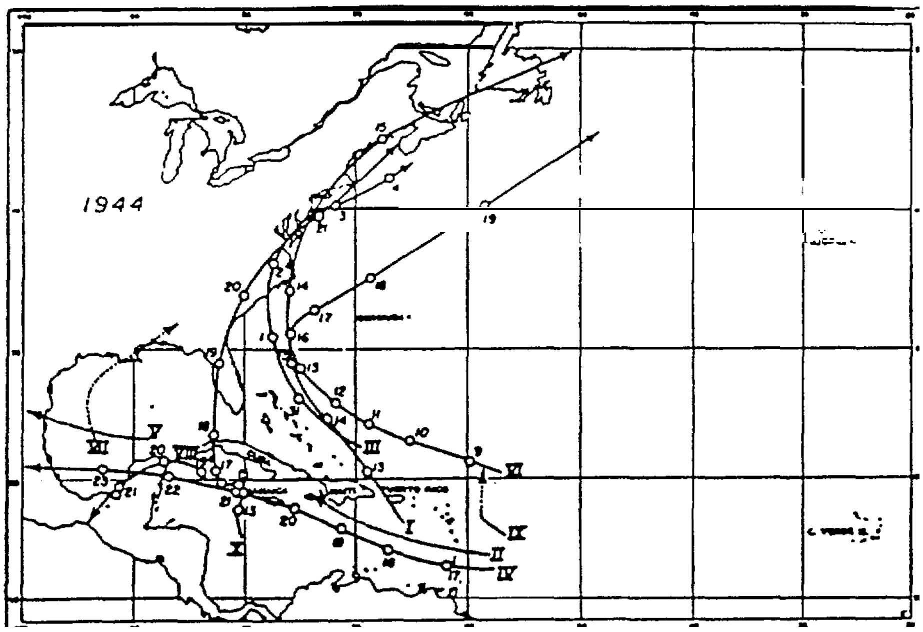

FIGURE F-59, Tracks of tropical storms of 1944. L July 13 to 19; II. July 25 to 26; III. July 31 to August 4; IV. August 17 to 23; V. August 20 to 22; VI. September 9 to 15; VII. September 9 to 10; VIII. September 19 to 21; IX. October 1 to 2; X. October 13 to 21.

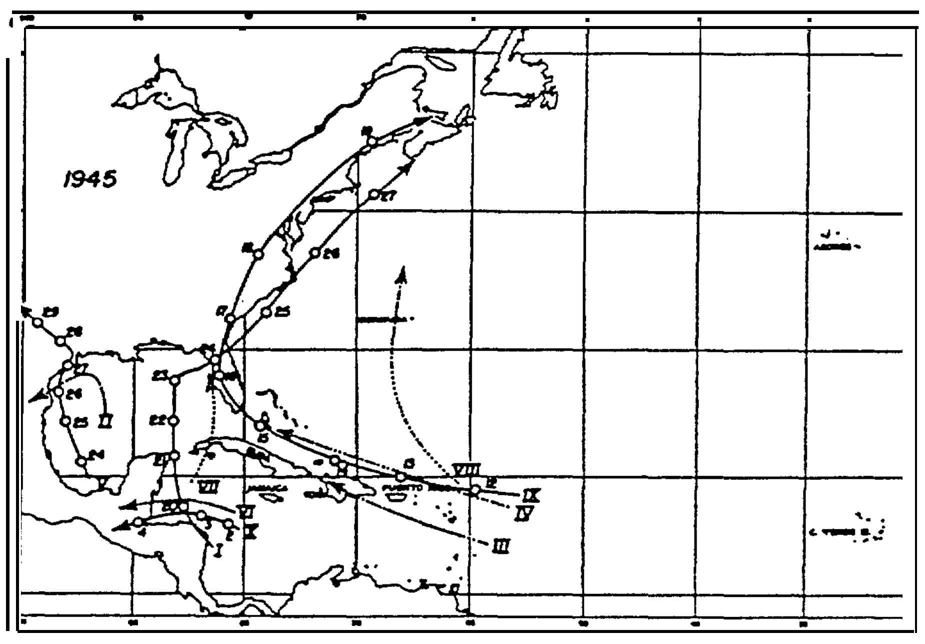

FIGURE F-60. Tracks of tropical storms of 1945. 1. June 20 to 27; II. July 19 to 21; III. August 2 to 4; IV. August 17 to 21; V. August 24 to 29; VI. August 30 to 31 ; VII. September 3 to 4; VIII. September 9 to 12; IX. September 12 to 19; X. October 2 to 4.

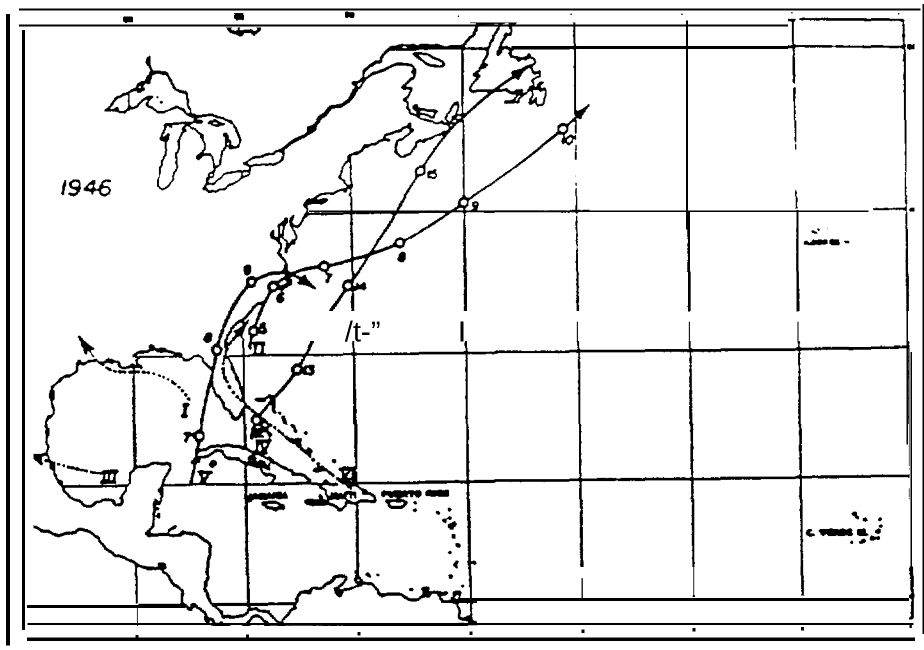

FIGURE F-61. Tracks of tropical storms of 1946. 1. June 14 to 16; II. July 5 to 10; III. August 25; IV. September 12 to 15; V. October 7 to 9; VI. October 31 to November 2.

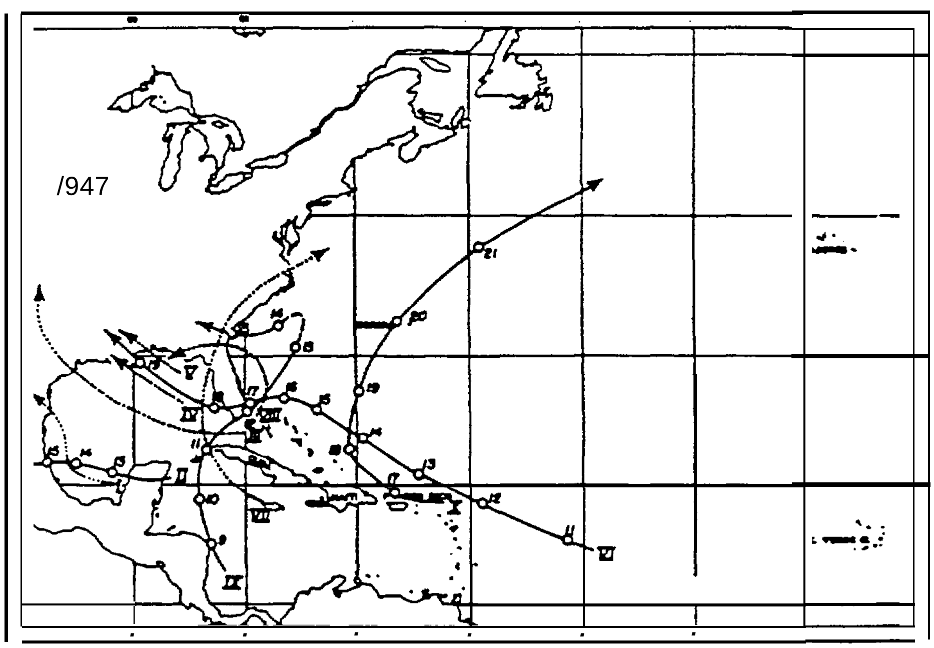

FIGURE F-62. Tracks of tropical storms of 1947. 1. July 31 to August 1; II. August 13 to 15; III. August 18 to 27; IV. August 21 to 22; V. September 7 to 8; VI. September 11 to 19: VII, September 20 to 25; VIII. October 6 to 7; IX. October "9 to 15; X. October 17 to 21.

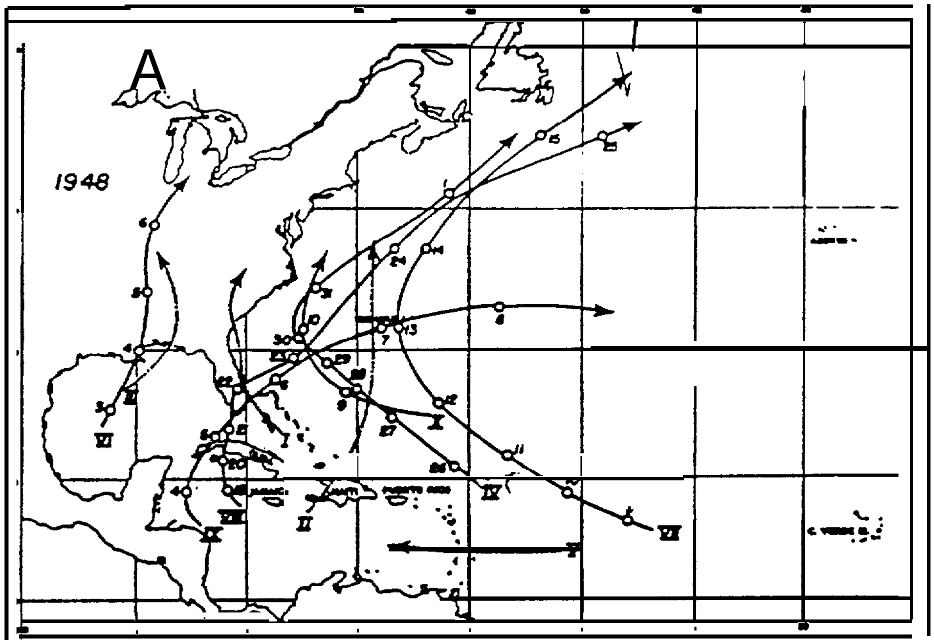

FIGURE F-63. **Tracks of tropical storms of 1948. L May 10 to 12; II. May 22 to 28; III. July 4 to 11; IV. 'August 26 to September 1; V. August 30 to September 2; VI. September** 3 **to** 6; **VII. September 9 to 15; VIII. September 19 to 25; IX. October 4 to 8; X. November** 9 to **10.**

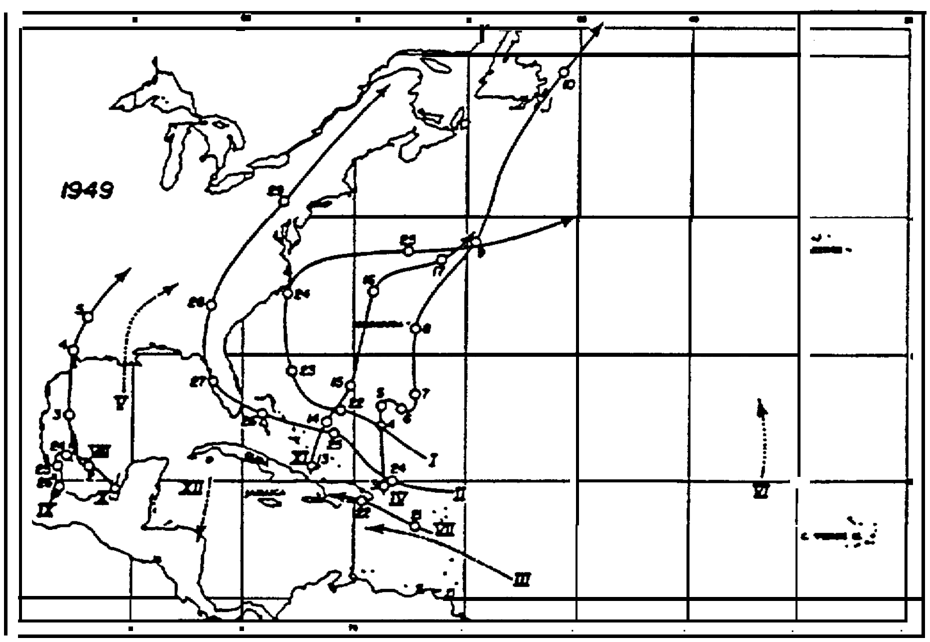

FIGURE F-64. **Tracks of tropical storms of** 1949. L **August 21 to 25: II. August 24 to 29; III. August 30 to September** 2; 'IV. **September 3 to 10; V. September 4 to 5; Vi. September 14 to 16; VII. September 21 to 22; VIII. September 22; 1X. September 24 to 26; X. October 1 to 5: xI. October 13 to 17; XII. November 3.**

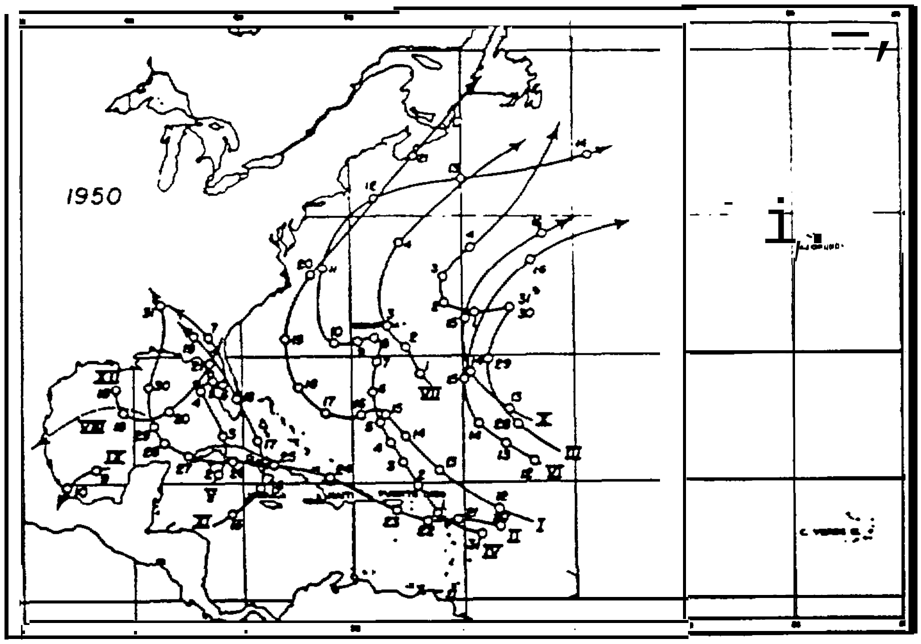

FIGURE F-65. Tracks of tropical storms of 1950. I. August 11 to 21; II. August 20 to 31; III. August 27 to September 4; IV. August 31 to September 14; V. September 1 to 7; VI. September 12 to 16; VII. October 1 to 4; VIII. October 2 to 4; IX. October 9 to 10; X. October 13 to 16; XI. October 15 to 19; XII. October 18 to 21.

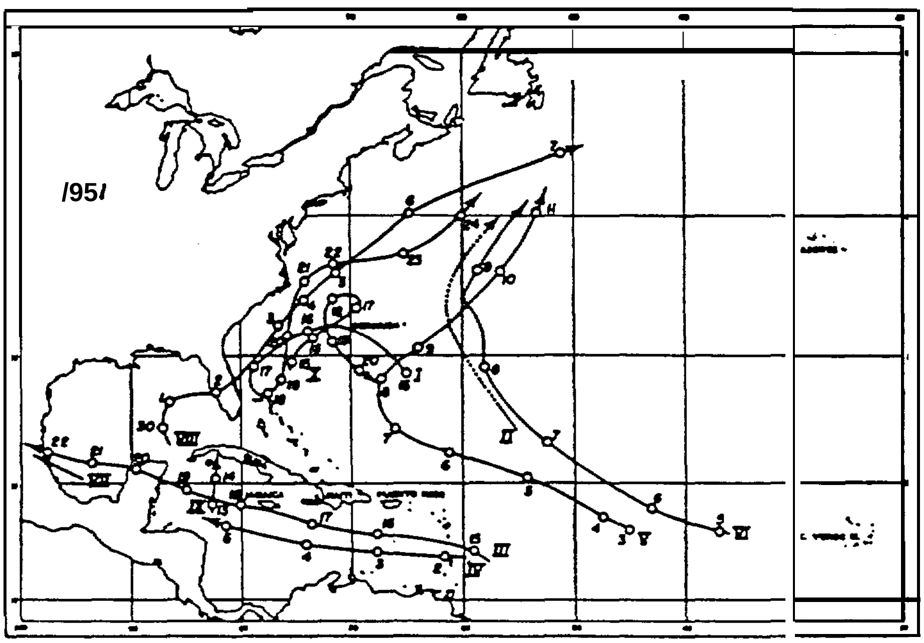

FIGURE F-66. Tracks of tropical storms of 1951. 1. May 15 to 24; II. August 3 to 5; III. August 15 to 22; IV. September 2 to 5; V. September 3 to-n; VI. September 5 to 9; WI. September 20 to 21; VIII. September 30 to October 7; IX. October 13 to 14; X. October 15 to 20.

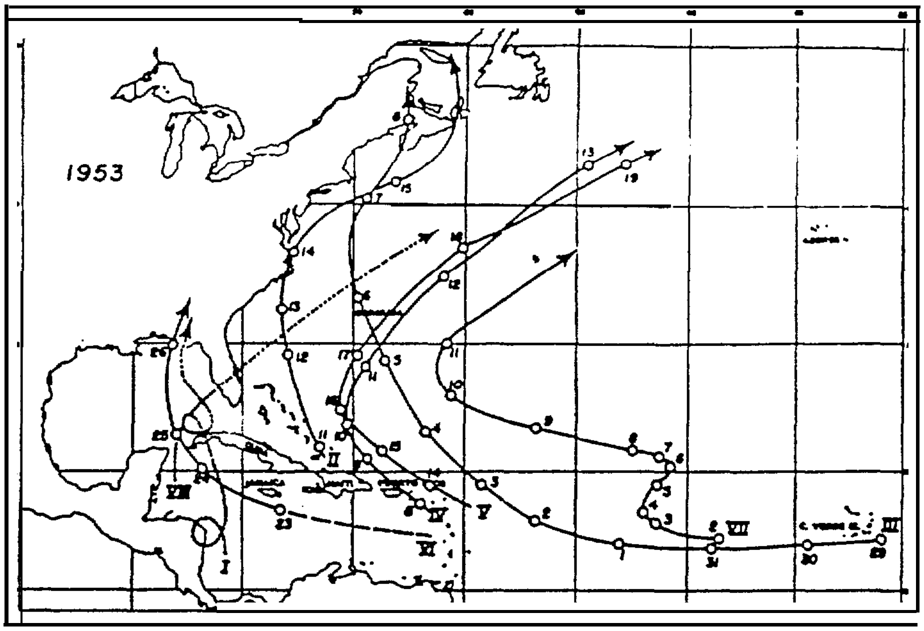

FIGURE F-67, Tracks of tropical storms of 1953. 1. May 25 to June 6; II. August 11 to 15; III. August 29 to September 8; IV. September 8 to 13; V. September 14 to 79; VI. September 23 to 26: VII. October 2 to 11: VIII. October 8 to 10.

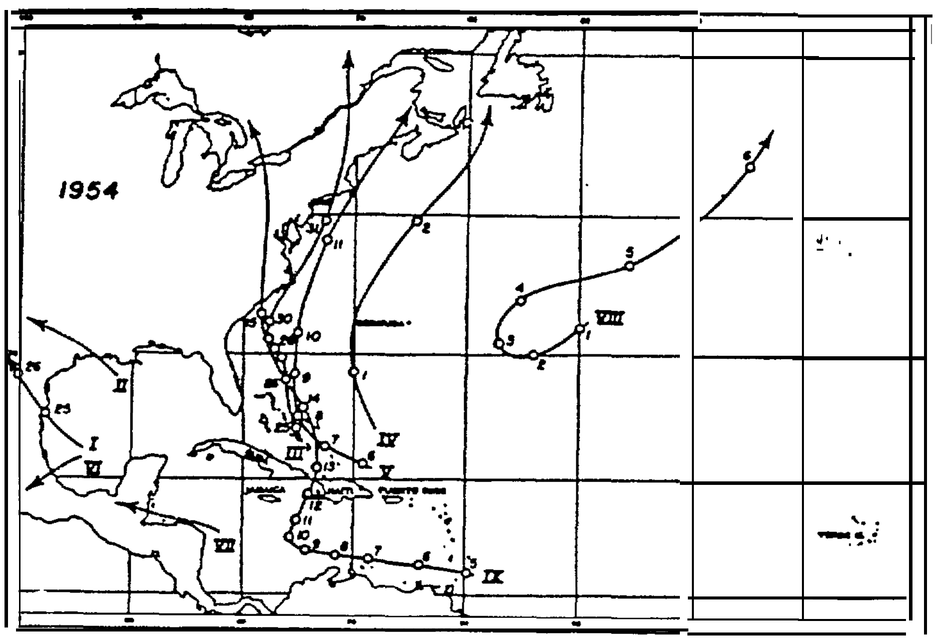

FIGURE F-68. Tracks of tropical storms of 1954. 1. June 24 to 26; II. July 28 to 29; III. August 25 to 31: IV. September 1 to 2; V. September 6 to 11; VI. September 11 to 12; VII. September 25 to 27; VIII. October 1 to 6; IX. October 5 to 16.

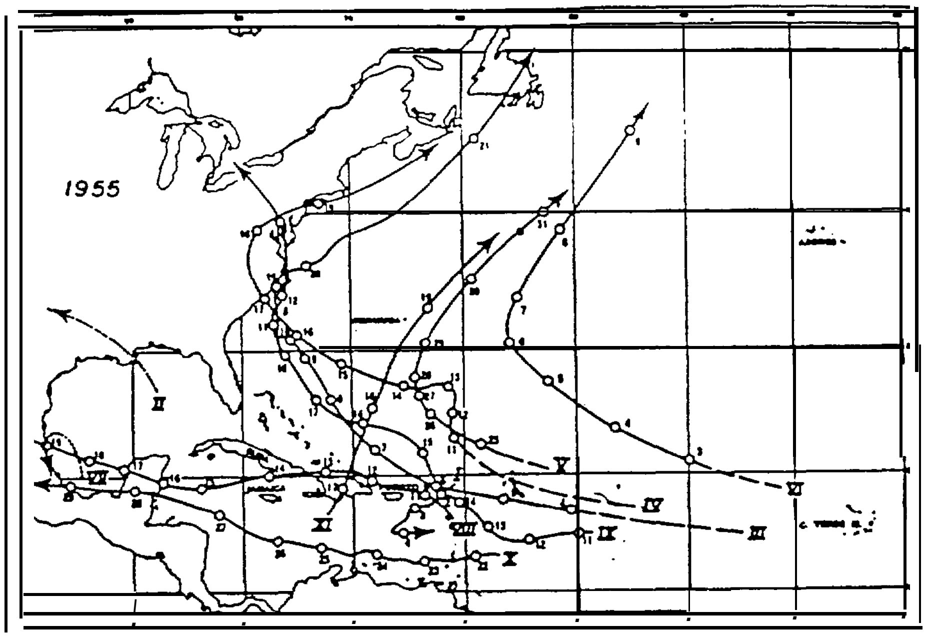

FIGURE F-69. Tracks of tropical storms of 1955, I. January 2 to 4: II. July 31 to August 2; III. August 3 to 13; IV. August 10 to 19; V. August 24 to 31; VI. September 3 to 9; VII. September 4 to 6; VIII. September 11 to 19; IX. September 11 to 21; X. September 22 to 29; XI. October 16 to 19.

APPENDIX G

Shipwrecks Contained in Lease Blocks

Table G-1.

Shipwrecks Contained in Lease Blocks.

SHIP NAME	YEAR	REF. NO.
LITTLE TY	0	182
UNKNOWN	0	522
UNKNOWN	0	433
ANCIENT MARINER	0	9
SANTA FEZ	0	297
UNKNOWN	0	446
JELYGE	0	139
UNKNOWN	0	569
COASTAL RAMBLER	0	63
LORI	0	183
UNKNOWN	0	527
UNKNOWN	c1	557
ALLEGRO	0	3
OFFSHORE	0	256
UNKNOWN	0	448
UNKNOWN	0	531
UNKNOWN	0	502
HAWAIIAN BREEZE	0	120
UNKNOWN	0	554
UNKNOWN	0	392
CAPT. CARL	0	47
WEST BEUFORT M.V	0	624
UNKNOWN	0	532
BULL	0	41
UNKNOWN	0	351
CAPT JACK	0	46
UNKNOWN	0	400
UNKNOWN	0	370
UNKNOWN	0	547
WA WA	0	622
UNKNOWN	0	44-r
UNKNOWN	0	594
BELLE	0	30
UNKNOWN	0	388
BARGER	0	22
SWIFT FISH	0	316
RIGHARD P	0	287
UNKNOWN	0	476
OBSTRUCTION	0	248
UNKNOWN	0	543
UNKNOWN	0	373
UNKNOWN	0	376
UNKNOWN	0	378
OBSTRUCTION	0	254
UNKNOWN	0	463
UNKNOWN	0	506
UNKNOWN	0	575
M. V. BARBARA	0	169
UNKNOWN	0	465
LUCILLE	0	186
UNKNOWN	0	597
YSD-71	0	632
BAHAMA MAMA	0	18
IJACKIE M	0	134
UNKNOWN	0	500
UNKNOWN	0	42B
JAN H	0	137
UNKNOWN	0	396
BLUEWATER No I	0	37
UNKNOWN	0	417
OBSTRUCTION	0	233
WILLIE D	0	626
UNKNOWN	0	550
CHEVRON OIL	0	5a
OBSTRUCTION	0	231
IMCO DRILLER	0	129
L AND L	0	156
UNKNOWN	0	587
UNKNOWN	0	462
JEFF DAVIS	0	13B
UNKNOWN	0	524
UNKNOWN	0	423
KERR MCGEE 11055	0	150
UNKNOWN	0	2733
UNKNOWN	0	555
UNKNOWN	0	399
UNKNOWN	0	564
OBSTRUCTION	0	240
OBSTRUCTION	0	239
BRETON ISLAND	0	39
UNKNOWN	0	545
BLUE WAVE	0	36
UNKNOWN	0	565
UNKNOWN	0	567
JO ANN	0	140
SHIP SHOAL	0	30B
Miss ELLEN	0	211
UNKNOWN	0	509
UNKNOWN	0	580
UNKNOWN	0	375
EMMA LOUIS	0	91
UNKNOWN	0	576
CORAL FAYE	0	391
UNKNOWN	0	561
UNKNOWN	0	558
UNKNOWN	0	350
G. I. JOE	0	105
UNKNOWN	0	568
OBSTRUCTION	0	246
UNKNOWN	0	461
UNKNOWN	0	389
LITTLE CRIS	0	176
UNKNOWN	0	606
INCOGNITO	0	130
CUAHUTEMOC	0	108
GREENWOOD	0	190
LASPRESIS	0	256
COLUMBIA	0	97
COLUMBIA	0	64
SAN PEDRO	0	126
SOUTH SEAS	0	429
UNKNOWN	0	539
UNKNOWN	0	372
UNKNOWN	0	549
LITTLE ELIJAH	0	179
UNKNOWN	0	496
OBSTRUCTION	0	237
UNKNOWN	0	526
CAPTAIN READY	0	54
ORION	0	260
UNKNOWN	0	403
UNKNOWN	0	411
TOOTS	0	330
UNKNOWN	0	599
UNKNOWN	0	541
CAPT CRICKET	0	44
CRANE	0	66
TERRY	0	320
UNKNOWN	0	470
UNKNOWN	0	603
UNKNOWN	0	355
UNKNOWN	0	409

TABLE G-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
UNKNOWN	0	662
UNKNOWN	0	186
UNKNOWN	0	421
UNKNOWN	0	512
UNKNOWN	0	407
OBS (HELICOPTER)	0	521
UNKNOWN	0	647
LUCKY FOUR	0	429
UNKNOWN	0	188
TX 6473	0	443
MAVERICK	0	340
OBSTRUCTION	0	205
UNKNOWN	0	232
UNKNOWN	0	367
UNKNOWN	0	393
DANL YN	0	480
UNKNO WN	0	68
STRANGER	0	518
UNKNOWN	0	313
UNK NO WN	0	573
UNKNOWN	0	440
PHIL ALICE	0	420
UNKNOWN	0	272
MARCO	0	520
UNKNOWN	0	198
TERRY LEE	0	34a
LUCKY	0	322
UNKNOWN	0	187
JOSEPH RUFF	0	466
UNKNOWN	0	236
MISS HAYES	0	608
UNKNOWN	0	212
FAITHFUL LADY	0	228
UNKNOWN	0	97
FLOSSIE R, SHAW	0	240
FLOSSEI R. SHAW	0	101
UNKNOWN	0	166
CAPTAIN GRIFFIN	0	410
BLUE BONNET	0	SO
LADY TONYA	0	3S
UNKNOWN	0	162
ALYSSA	0	488
UNKNOWN	0	4
LYCO I	0	511
DOLPHIN	0	284
UNKNOWN	0	74
M901	0	501
M905	0	191
UNKNOWN	0	192
MR B	0	477
UNKNOWN	0	219
UNKNOWN	0	454
AMAYS	0	584
UNKNOWN	0	6
UNKNOWN	0	366
UNKNOWN	0	479
JOLLY ROGER	0	471
LADY VERNE	0	143
UNKNOWN	0	163
UNKNOWN	0	609
OBSTRUCTION	0	439
UNKNOWN	0	251
MISS LAURA	0	560
UKDLA	0	215
UNKNOWN	0	344
	0	S82

SHIP NAME	YEAR	REF. NO.
PERAMA	0	271
HELO	0	125
FRANCES	0	104
WRECKAGE	0	628
VAINQUEUR	0	616
GULFSTAG	0	115
UNKNOWN	0	371
UNKNOWN	0	404
UNKNOWN	0	382
UNKNOWN	0	363
UNKNOWN	0	424
UNKNOWN	0	452
UNKNOWN	0	519
UNKNOWN	0	460
UNKNOWN	0	414
LINDA LOU	0	175
EAGLES CLIFF	0	86
UNKNOWN	0	563
DUBHE	0	81
TRIESTA	0	337
UNKNOWN	0	346
UNKNOWN	0	387
EXCALIBER	0	96
UNKNOWN	0	458
UNKNOWN	0	419
OBSTRUCTION	0	244
UNKNOWN	0	552
JULIE ANN	0	147
PENROD 52	0	269
BECK II	0	27
UNKNOWN	0	595
UNKNOWN	0	386
UNKNOWN	0	362
UNKNOWN	0	368
OBSTRUCTION	0	241
SHELL DRILLER	0	306
UNKNOWN	0	612
PIONEER	0	273
SAMMY J	0	292
OBSTRUCTION	0	230
OBSTRUCTION	0	253
UNKNOWN	0	529
UNKNOWN	0	393
UNKNOWN	0	600
UNKNOWN	0	3s7
LOUIS	0	184
UNKNOWN	0	469
LA ENGLE	0	157
UNKNOWN	0	456
EDGAR F CONEY	0	389
SARAH MARIE	0	29s
CLARA ANNEK	0	61
UNKNOWN	0	398
TRADEWIND	0	333
U 2513	0	65
JUNO	0	148
UNKNOWN	0	605
UNKNOWN	0	540
OBSTRUCTION	0	243
GANDY DANCER	0	107
HIGH STEPPER	0	127
UNKNOWN	0	593
UNKNO WN	0	646
OUTLAW	0	262
UNKNOWN	0	508
KINGFISHER	0	154

TABLE G-I (CONTINUED).

SHIP NAME	YEAR	REF. NO.
TRI-FISH	O	335
UNKNOWN	O	534
UNKNOWN	O	379
UNKNOWN	O	384
UNKNOWN	O	566
OCEAN BELLE	O	255
MISS EILEEN	O	210
MABEL F II	O	193
UNKNOWN	O	487
UNKNOWN	O	413
UNKNOWN	O	491
UNKNOWN	O	467
GELMER	O	108
UNKNOWN	O	571
NEw MOON	O	224
UNKNOWN	O	361
UNKNOWN (GIGI IV)	O	613
MOONRAKER	O	218
TExACO 157	0	323
CONT 112 22	0	65
BUCCANEER	O	40
BARGE R. O. 2.	0	21
UNKNOWN	O	478
THERESA F	O	326
UNKNOWN	O	356
TUFFY	O	338
UNKNOWN	O	359
UNKNOWN	O	551
UNKNOWN	O	437
MARVINA	O	202
IJAMES I	O	135
UNKNOWN	O	516
JAMESI	O	136
UNKNOWN	O	559
UNKNOWN	O	435
UNKNOWN	O	548
DOROTHY GLORIA	O	76
UNKNOWN	O	43s
UNKNOWN	O	504
FIVE BROTHERS	O	100
NEW HOPE	O	223
HELEN MARTIN	O	124
UNKNOWN	O	525
UNKNOWN	O	536
LITTLE GENERAL I V	O	180
MICHELLE DESLETTES	O	208
UNKNOWN	O	572
UNKNOWN	O	459
UNKNOWN	O	450
OBSTRUCTION	O	250
UNKNOWN	O	385
UNKNOWN	O	405
SINTPAT	O	310
UNKNOWN	O	369
UNKNOWN	O	489
UNKNOWN	O	449
KOKOMO	O	155
UNKNOWN	O	537
OBSTRUCTION	O	236
CLIPPER	O	62
SANDRA F	O	295
UNKNOWN	O	601
DOS HOMBRES	O	77
UNKNOWN	O	416
UNKNOWN	O	431
UNKNOWN	O	602

SHIP NAME	YEAR	REF. ND.
UNKNOWN	O	585
CHIP	0	59
SUZANNE	0	315
HAZEL FOSTER	0	121
MIDCO	0	209
UNKNOWN	0	427
UNKNOWN	0	360
MR MAGOO	0	220
BILL H	0	34
LAURA E	0	166
EMILE T EYMARD	0	80
SAN JORGE	1625	344
LA BELLE	1685	233
AIMABLE	1685	19
UNKNOWN	1700	
NUESTRA SRA. AMPARO	1717	314
N.ESRA. OEL AMPARO	1717	314
UNKNOWN	1725	
LA PRINCE DE CONTY	1731	
VIGILANTE	1732	
LA LOUISIANE	1738	
UNKNOWN	1741	
LE SUPERB	1745	263
DOLPHIN	1748	124
BETSEY	1750	58
ALEXANDER	1752	12
DOLPHIN	1752	123
STATEA	1752	429
LANCASTER	1752	253
UNKNOWN	1752	516
MAY	1752	289
UNKNOWN	1752	493
RHOOE ISLAND	1752	379
UNKNOWN	1766	468
UNKNOWN	1766	475
LA CARAQUENA	1776	234
UNKNOWN	1777	
ROBERT	7777	
GALGO	1783	
ARAUCANA	1611	
ATLAS	1816	43
LEOPARO	1825	242
RuFuS PUTNAM	1825	361
MONROE	1826	323
WASHINGTON	1029	527
REGULATOR	1830	384
UNKNOWN	1830	470
FREDERICK	1830	170
PIZARRO	1831	370
PACIFIC	1s31	347
PETTIT NANCY	1631	364
NATIVE	1832	333
CHAMPION	1832	75
PENNSYLVANIA	1835	361
SOPHIA	1835	428
RUTH	1835	399
SAN FELIPE	1835	375
HANNAH ELIZABETH	1835	166
ST. ISABEL	1836	401
JAMES X. TIMPSON	1836	219
CAYUGA	1836	74
SAN FELIPE	1636	552
PELICAN	1B36	359
HENRY	1837	201
WILLIAM	1837	532
UNION	1837	463

TABLE G-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
CRUSADER	1838	107
CONSTITUTION	1840	102
CHANCELLOR	1841	75
GENERAL BRYAN	1842	150
MARY	%842	42
SWAN	1843	73
SARAH BARNES	1843	67
ALEXANOER WASHINTON	1844	1
LLEWELLYN	1844	37
SOBIESKI	1844	69
J.D. NOYES	1844	28
TIGER	1844	418
SWALLOW	1845	72
NEW YORK	1846	51
NEPTuNE	1846	334
GOPHER	1846	186
FLORIDA	1846	165
TARRY NOT	1846	442
TWO BROTHERS	1846	459
SEA	1846	418
PALO ALTO	1846	350
VAN BUREN	1846	77
PANAMA	1846	56
BLACK HAWK	1846	3
MARGARET	1846	40
FRONTIER	1846	171
PAULINE	1846	57
HAMLET	1846	24
J.T. BERTINE	1846	29
COLONEL HARNEY	1847	91
SARAH	1847	416
ALICE SADELL	1847	20
A.B. COOLEY	1848	3
GLOBE	1851	182
SPRAY	1851	432
PALMETTO	1851	348
INDEPENDENCE	1852	192
METEOR	1852	315
CINCINNATI	1853	77
UNKNOWN	1853	555
UNKNOWN	1853	485
CINCINNATI	1853	81
YACHT	1853	540
UNKNOWN	1854	479
MAGYAR	1854	238
J.J. WARREN	1859	203
OK	1862	316
ELMA	1862	125
MORNING LIGHT	1863	326
REvENGE	1863	391
MANHASSET	1863	291
USS MORNING LIGHT	1863	445
YOUNG HARRY	1863	S42
NASSAU	1863	2S8
NASSAU	1863	332
KATE	1863	243
I.W. HANCOX	1863	206
BLOSSOM	1863	49
ZEPHIR	1863	544
PARTRIDGE	1863	351
RELIEF	1863	388
VICTORIA	1863	521
USS HATTERAS	1863	443
HATTERAS	1863	168
CLIFTON	1864	87
MARY ANN	1864	299
MARY ANN	1864	270
UNKNOWN	1864	484
RCB ROY	1865	352
EXCELSIOR	1865	153
ANNA OALE	1865	24
UNKNOWN	1865	464
ELLA	1866	138
L'ECLAIR	1866	247
RINALDO	1866	392
PATOMSKIA	1866	352
ALEXA	1866	11
EDITH BROWN	1867	130
CHIEF	1867	79
UNKNOWN	1867	494
TARTAR	1867	443
MOUNTAIN HOME	1867	327
UNKNOWN	1067	474
UNKNOWN	1067	488
VOLUMNIA 25748	1867	524
BILLOW	1868	47
SAINT MARY 23664	1868	406
MARIPOSA	1870	280
QUEEN OF THE SEAS	1870	378
SUN FLOWER	1870	406
IDA REES	1873	191
S.S. PAISANO	1873	335
ODELIA 19267	1874	342
MARION	1874	295
MARY CAROLINE 16691	1874	301
TEXAS RANGER	1874	450
ADA	1875	6
REINE OES MERS	1875	387
RESCUE	1875	389
OESPERAOO	1875	
JONAS H. FRENCH	1875	
IDA LEWIS	1875	207
WESTERN EMPIRE	1875	
OEMOCRAT 6465	1875	114
BURKHART	1876	56
GEORGE BURKHART	1876	177
THISTLE	1877	415
WOODHOUSE	1877	465
E.S. TYLER	1877	125
CLARA WOODHOUSE	1877	83
FAIRY 9902	1877	156
THREE SISTERS	1877	
GOVERNOR MORTON	1877	147
EMMA	1878	142
TORRY	1878	421
RHODA B. TAYLOR	1878	351
BEST FRIEND	1879	43
J.D. WILLETS 13807	1880	240
CATON	1s80	72
MARIE THERESA	1880	294
LAURA LEWIS 15968	1880	257
NONESUCH	1880	.
WELCOME	1880	457
PETRITA 20307	1880	363
MARIA THERESA	1880	293
R.D. PIPER	1880	380
WELCOME	1880	
UNKNOWN	1881	496
JWAY M. (?)	1881	22s
JOSEPHINE	1881	222
WHISPER 80460	1881	529
VALLEY CITY	1882	546

SHIP NAME	YEAR	REF. NO.
TWO MARY'S	1882	
TEX MEX	1882	
ROSETTA MCNEIL	1882	476
POSETTA MCNEIL	1882	336
ANNIE LEWIS	1883	.
SAM HOUSTON	1883	369
LAURA	1884	238
DORIO DORIA	1885	120
PHEONIX	1886	365
LOTTIE MAYO	1886	.
ARIETAS	1886	37
QUINTANA 20562	1887	379
MINNIE	1888	255
ANTONIETTA	1888	.
EAGLE	1880	113
RIPPLE	1889	
L.A.BURHAM	1889	.
REBECCA 21860	1889	383
NUEVO CURRUTACO	1809	2%7
FANNIE	1889	
MAGGIE 91447	1890	289
MATTIE	1891	312
FRANK HITCHCOCK	1893	169
WALTER L. PLUMMER	1894	.
G.G.O.	1895	
CRISIS	1895	.
JAMES ANDREWS	1896	217
GERHARDUS	1897	
UNKNOWN BARGE	1897	500
SEA GULL	1097	422
HENRY C. WINSHIP	1897	175
HATTIE	1898	199
WILLIAM J. KEYSER	1 8 9 8	
MARJORIE	1899	
HELENA E. RuSSELL	1899	
JOHN S. AMES	1899	
ABBIE OEES	1899	.
COQUETTE	1 900	103
CAROLINE	1900	67
REGULATOR	1901	.
MABEL HOOPER	1901	.
LIZZIE HAAS	1902	246
HELEN BUCK	1902	.
CAROLINE	1902	66
MARY E. LYNCH	1902	302
JOSEPHINE O.	1903	237
E.H. WEAVER	1903	457
LAKE AUSTIN	1903	253
EL MAR	1904	133
HANNAH	1905	197
VILA Y. HERMANO	1905	392
NOKOMIS	1905	227
ELMER E. RANDALL	1906	112
A.A. ROWE -	1906	1
G.L. DABOLL	1906	592
FRED P. LITCHFIELD	1 906	132
ASA T. STOWELL	1906	39
E.L. NOTTINGHAM	1906	145
E L NOTTINGHAM	1906	83
EMMA L. NOTTINGHAM	1906	113
FLYTDN	1906	562
ELSIE MARIE	1 907	493
ADDIE F. COLE	1908	6
VICTORINE	1908	1609
NORTHERN EAGLE	1908	1206
JERRY	1909	200

SHIP NAME	YEAR	REF. NO.
COLUMBUS	1909	354
ISAAC T. CAMPBELL	1909	
LYOIA	1909	988
FRANCES H.	1909	571
EONA B.	1909	131
JAMES C. CLIFFORD	1909	
HARRY K. FOOKS	1910	683
SATURN	1910	1430
CLARKE OIL TNKR #1	1911	05
RACHEL EMERY	1911	315
BARGE NO. 14	1912	38
N.A.D. CO. NO.5	1912	1173
N.A.D. CO. NO.6	1912	1174
T.T. CO. NO.11	1912	1530
S.O.CO. NO.87	1912	1398
TAURUS	1912	1532
BISCAYNE	1913	46
MILDRED	1914	283
PRISCILLA	1914	1310
NELLIE GRANT	1915	1183
LYDIA M. DEERING	1915	
DORIS	1915	438
OONNA CHRISTINA	1915	107
THEOOORE WEEMS	1915	
MAUDE PALMER	1915	1054
CHICOPEE	1915	78
EMMA HARVEY	1916	502
JENNIE S. HALL	1916	779
MARION R	1916	1027
BRADFORD C. FRENCH	1916	
C STRONG	1916	43
C. STRONG	1916	122
CARRIE STRONG	1916	297
METEOR	1916	1069
SUSIE H. DAVIDSON	1917	371
PATTON	1917	294
DEAN E. BROWN	1917	401
MAGGIE TOOO	1918	275
GUYTON NO.10	1918	672
SPRINGFIELD	1918	
FAIRHOPE	1918	121
MILLIE R. BOHANNAN	1919	1075
JOHN FRANCIS	1919	800
JOHN SEALY	1919	233
CAPE HORN	1919	61
MUNISLA	1919	273
CORYDON	1919	111
MARIE	1919	1020
DETROIT	1919	91
SAVERIO M. STELLA	1920	1431
CAPTAIN SAM	1920	275
THREE MARYS	1920	327
SPEEDWELL	1s20	.
HOLLISWOOD	1920	714
CRESCENT	1920	114
MINGO	1920	
GUNN&ANDERSON BROS.	1921	
G. A. SOMERVILLE	1921	614
J.W. SOMERVILLE	1921	758
G.C.T. CO.16	1921	590
ALLEGHENY	1921	
BEN	1921	32
BAN	1921	430
C. W. WELLS	1s21	78
C.W. MILLS	1921	79
JESSIE C. BARBOUR	1922	209

TABLE G-1 (continued).

SHIP HAME	YEAR	REF. No.
JESSE C. BARBOUR	1922	189
GOLDEN STATE	1922	144
NOLA	1922	
FIDGET	1923	540
CASTINE	1924	60
GRADY S.	1924	637
FANNIE AND FAY	1925	532
HORACE M. BICKFOR'D	1925	.
THE LMA	1925	.
M.N. COBB	1925	280
MARION N. COBB	1925	246
W.D. CASH	1926	1626
GULF OF MEXICO	1926	656
HELENA	1926	695
LADY BERTHA	1926	881
YUMA	1926	633
ELLEN C. BURKE	1927	489
W H MARSTON	1927	621
W.H. MARSTON	1927	395
MARY	1930	4175
EOGAR F. CONEY	1930	.
E.F. CONEY	1930	675
BUCCANEER	1933	220
PROVIDENCIA	1936	1315
LINDE NO.5	1936	S35
IDA Q	1936	731
E. J. BULLOCK	1938	129
UNKNOWN	1939	441
BELMONT	1939	31
SHAMROCK	1939	1452
KIVA	1939	212
J W CLISE	1940	133
J.W. CLISE	1940	183
TEXAS NO.2	1941	1541
EDGAR M.	1942	468
MERRIMACK	1942	1066
IJOSEPH M. CUDAHY	1942	820
GEORGE C. GREER	1942	602
U-166	1942	273
R.M. PARKER JR.	1942	272
R M PARKER JR.	1942	279
WM. C. McTARNAHAN	1942	403
HEREDIA	1942	246
R W GALLAGHER	1942	200
R.W. GALLAGHER	1942	240
BAJA CALIFORNIA	1942	19
MUNGER T. BALL	1942	272
DAVID MCKELVY	1942	673
UNKNOWN	1942	435
BAYARD	1942	24
UNKNOWN	1942	230
GUNBOR	1942	116
NORLINDO	1942	70
TORNY	1942	331
SHEHERAZADE	1942	265
CIT S TOLEDO	1942	60
CITY OF TOLEDO	1942	324
EDWARD LUCKENBACK	1942	72
EO LUCKENBACH	1942	643
ONTARIO	1942	259
B-1	1942	102
BENJAMIN BREWSTER	1942	23
B BREWSTER	1942	16
EMPIRE MICA	1942	92
HERMIS	1942	47
VIRGINIA	1942	620

SHIP NAME	YEAR	REF. No.
RAwLEIGH WARNER	1942	291
GULFOIL	1942	152
GULF OIL	1942	211
GULF PENN	1942	243
ROBERT E. LEE	1942	323
ALCOA PURITAN	1942	1
R E LEE	1942	278
R.E. LEE	1942	261
CARRABELLE	1942	56
AMAPALA	1942	5
GEORGE CALVERT	1942	603
UNKNOWN	1943	412
ARIZONA	1943	82
UNKNOWN	1943	202
UNKNOWN	1943	651
UNKNOWN	1943	482
PRAwN	1943	1299
TuLSA	1943	436
UNKNOWN	1943	667
SUNSHINE	1943	1518
ANONA	1944	341
SEA OUKE	1944	1436
'f? 331	1944	66
EAGLE	1945	84
ANTONIA ENSEN	194s	12
EL VIVO	1945	342
MARGATE	1945	313
UNKNOWN	1946	579
SUNSHINE	1946	1519
ANACONDA	1946	8
GULF TIDE	1947	362
LEO HUFF	1947	170
DONNA LEE	1947	434
VALKYRE	1947	1599
WINTHROP	1947	402
WARRIOR	1947	1635
UNKNOWN	1947	495
S. C. LOVELAND JR.	1948	395
RAY SCOTT	1948	1335
SUNBEAM	1948	369
HELEN L	1948	692
IRVIN	1948	742
SAN MARCOS	1948	
S.C. LOVELAND	1948	311
S C LOVELANO	1948	2B9
UNKNOWN	1948	515
FL'S TRAILBLAZER	1949	556
CARMEN LOUISE	1949	287
STARLAN	1949	1500
LITTLE TOM	1949	956
THE SHARK	1949	1551
MERIDA	1949	
RUMA	1949	328
DOROTHY	1949	440
UNKNOWN	1949	294
WILDA L.	1949	1649
JOGUY	1950	798
RECESS II	1950	1340
NORTHER	1950	338
HAZEL C	1950	687
COASTWISE	1950	349
TROUT	1950	1581
BERTHA S.	1950	144
BETTY	1950	152
E.M. HARTWICK	1950	459
SILVER LINER	1951	357

SHIP NAME	YEAR	REF. No.
VIRGINIA MAY	1951	555
GEN. PAPAGOS	1951	599
CUAHUHTEMUC	1951	114
LADY MAE	1951	216
MACKEREL	1951	996
ANNE HARDY	1951	11
MARY-JOHN	1951	1050
HILDA B	1951	709
GEORGIANA	1951	610
EDNA BELLE	1951	470
ATHENS	1951	94
WRECK	1951	627
UNKNOWN	1951	141
DAHLIA	1952	386
RITA	1952	1355
CHIC	1952	323
EVELYN JEWELL	1952	119
ALERT	1952	35
ARMY	1952	86
MERRY SEA	1952	1067
PARNELL	1952	1250
GREEN SEAS	1952	185
JANET ANN	1953	770
WEST BEUFORT	1953	423
VERMILION	1953	1605
KILE NO.1	1953	859
LITTLE CHRIS	1953	273
CANNON BALL	1953	47
BOUNTY	1953	38
F.W. SHEPER	1953	526
USS PC 463	1953	101
PENTREL 14	1953	270
BARBARA ANNE	1953	118
TEXAS NO.7	1953	1542
CLIPPER	1953	347
VONCILLE	1953	1625
CAYO HUESO	1953	306
DOLPHIN	1953	428
LITTLE HOWDY	1953	948
LINDA	1954	173
OR. H.E. WHITE	1954	449
ATLANTIC	1954	15
MAMIE J.	1954	1007
R.J.L.	1954	1322
POLARIS	1954	303
AMIGA MIA	1954	20
PALMETTO	1954	348
H. FINN	1954	195
CAMPECHE	1954	238
H FINN	1954	117
IJIM MELTON	1954	705
GMOCO	1954	625
LIBERATOR	1954	814
FLAGSHIP	1954	126
BLUE STACK 79	1954	174
GYPSY GIRL	1954	194
DOROTHY	1954	441
UNKNOWN	1954	177
HILL	1954	710
UNKNOWN	1954	654
UNKNOWN	1954	176
VIRGINIA GAIL	1954	1616
UNKNOWN	1954	4190
VIKING	1954	1611
LIBORIA C,	1954	268
SAM HOUSTON	1954	337

SHIP NAME	YEAR	REF. NO.
3&1&1	1954	1
C.D. ERGAS	1954	227
WA WA	1954	424
CARIBE NO.500	1954	327
PIONEER	1954	330
BERTHA R.	1954	
ROSIE 11	1954	389
PEARL LOUISE	1954	1261
HUCKLEBERRY FINN	1954	719
LEE HARDIMAN	1954	903
SHOAL HARBOR	1955	390
CHIEF	1955	325
LOUFAYTERRY	1955	228
RAMOS 111	1955	676
RAMOX 111	1955	392
UNKNOWN	1955	644
LINDA LEE	1955	934
BLUE EONNET	1955	182
SNAPPER QUEEN	1955	1473
JEAN	1955	775
CORAL SANDS	1955	82
JOSEPH ANTHONY	1955	199
CONQUEST	1955	359
BON SECOUR	1955	196
ELECTRA	1955	134
ARROW	1955	13
ARROW	1955	32
KERMAC XVI	1955	853
KERMAC XVI	1955	209
SHOAL HARBOUR	1955	356
ESMERALDAS	1955	116
OBSTRUCTION	1955	242
UNKNOWN	1955	310
MISS CONSTANCE	1955	1096
OBSTRUCTION	1955	245
UNKNOWN	1955	302
SUNSHINE	1955	1517
DEWEY	1956	71
SANDY HOOK	1956	1421
SHOAL HARBOR	1956	309
UNCLE LUM	1956	1592
CHALLENGER	1956	309
POLARIS	1956	386
DELTA JR.	1956	413
MUTINY	1956	275
DONALD FAYE	1956	430
LOT BESCO	1956	373
LCT BESCO	1956	168
ANGELOS	1956	9
VONA MABRY	1956	1624
MAYFLOWER	1956	1061
NEW LIFE III	1956	1191
SUSAN & GRETTA	1956	370
VIVIAN TILLMAN	1956	1621
ELIZABETH	1956	4a 1
V TILEMAN	1956	263
AGEOS SPERIDON	1957	22
PELICAN DRILLER	1957	295
J.A. BISSO	1957	.
J E BISSO	1957	132
MURMANILL	1957	221
TWIN BROTHER	1957	1586
RUTLIDGE	1957	400
CAPT GENE	1957	246
ANSON T.	1957	7a
EMILY INEZ	1957	499

TABLE G-1 (CONTINUED).

SHIP HAME	YEAR	REF. No.
LITTLE JEWEL	1957	949
SALLY ANNE	1957	1409
DIXIE DANCY	1957	118
BLUE FIN	1957	32
ATLANTA	7957	34
CHEBEAGUE	1957	318
MARGARET M.	1957	292
EVA ROSE	1957	151
NIKE	1957	1196
MARY ELLEN	1957	1042
WILLIAM HAYES	1957	625
KETURAH	1957	210
STAR DUST	1957	1497
RANGELY	1957	316
MARY ANNE	1957	1037
RALPH E. HAVENS	1957	1328
NEW REGAL	1957	1193
GERALDINE	1957	611
UNKNOWN	1957	390
TROPICAL	1957	
DOTTIE NELL	1957	446
BOY SCOUT	1957	3243
D-17	1958	381
SUPERTEST	1958	434
BECKY SUE	1958	19
MISS CAMPECHE	1958	298
WALLING III	1958	56?
SAMMY H.	1958	339
OCEAN BRIDE	1958	1212
UNKNOWN	1958	665
TIMMY	1958	1565
YANKEE PIRATE	1958	406
ST. MARK	1958	1493
FRANCES	1958	131
SHELL DRILLER	1958	355
ALABAMA	1958	20
CATHI E	1958	303
ECHO	1958	463
PRINCESS PAT	1958	1308
AUOREY	1958	99
MARTHA GENE	1959	1034
MR. BILL	1959	271
TRANS-GULF NO.10	1959	1577
IJOSEPH H. DAVI	1959	819
G. MO. MARCONI	1959	588
CAROL FAYE	1959	56
SOUTHERN QUEEN	1959	1480
RUTHELINE	1959	1393
QUE NO.3	1959	1317
BUCKROY	1959	221
LITTLE SARAH	1959	855
SYLVIA H.	1959	373
INEZ G	1959	4155
DRYDOCK	1959	80
GLEN-RAE	1 959	181
MISS LDU	1959	1119
NANCY F.	1959	276
FAITH	1959	529
SAILDR	1959	1406
OTTIS	1959	1237
PHILOMENE	1959	299
C.M. BOGGS	1959	45
VELMA	1959	1603
D-15	1959	380
J.S. OTIS	1959	756
MISS MINNIE	1959	1123

SHIP NAME	YEAR	REF. No.
MISS BARBARA ANN	1959	256
40_FATHOM NO.27	1959	6
LAVENA	1959	167
ROSEINA	1959	288
CHEROKEE	1959	69
ELINOR-J	1959	479
HUSTLER	1959	722
JUJUBEE	1959	203
CHERIE	1960	321
RAMOS PR1OE	1960	283
DRAGONET	1960	79
ECLIPSE II	1960	465
MARY JOHN	1960	1047
GULF STREAM	1960	150
POP EYE	1960	1295
LI'L TEXAN	1960	222
LIL TEXAN	1 960	921
MISS MORGAN CITY	1960	1124
fish haven	1960	635
FISH HAVEN	1960	160
FIGHTER	1960	542
KATY D.	1960	848
MISS GINA	1960	260
DOCTOR WALLING	1960	94
UNKNOWN	1960	465
UNKNOWN	1960	659
LITTLE MITCH	1960	225
UNKNOWN	1960	395
40_FATHOM NO.6	1960	7
TEXAS NO.11	1960	1540
ROWENA BURGMAN	1960	326
MISS CATHERINE	1960	257
LONGHORN	1960	227
SEA GULL	1960	1437
GEORGIA QUEEN	1960	608
THERESA F.	1960	1554
LITTLE DAVID	1960	842
TRICIA F	1960	336
BLANCHE MARIE	1960	180
LADY LILLIAM	1960	887
CARLTON EACHO	1960	285
SANTA FE	7961	1424
TRVELER	1961	1582
JANIS WALKER	1961	186
MABEL MARLJEAN	1961	994
POMPANO SCOUT	1961	1293
TRAVELER	1961	385
MILLIE	1961	1074
KELLY K	1961	852
KELLY K.	1961	208
JOROAN GIRLS	1961	817
HI -WAY	1961	706
CORAL CLIPPER	1961	363
RODNEY	1961	1368
MISS MYRTLE	1961	1125
UNKNOWN	1961	3597
ROSE CROIX	1961	325
SHERRY ANN	1961	307
DONNA K	1961	433
K.	1961	242
ISLANDER	1961	267
FEARLESS	1961	124
TUG	1961	339
TWO SISTERS	1961	1589
SANTA MARIA	1961	1425
TONY S.	1961	1571

TABLE G-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
UNKNOWN	1961	672
FAWN	1961	534
ISLANDER	1961	131
THE GEORGE QUEDNAU	1962	1547
TOOTS	1962	1573
GUIDING LIGHT	1962	645
SALLy GALE	1962	1410
SIDNEY JR.	1962	1464
WILLIAM R.	1962	570
COMANCHE	1962	355
ALLEGRO	1962	42
UNKNDWN	1962	661
CAPTAIN JIMMIE	1962	50
PETRO PETE	1962	1272
HEEDLESS	1962	166
MARINE SU. QUEEN	1963	.
S.S, SPENCE	1963	1400
UNKNOWN	1963	396
JOLIE BLONDE	1963	814
DAVID B	1963	110
LUA	1963	233
MISS NORTH CAROLINA	1963	1127
CHUCKADEE 11	1963	70
CAPTAIN TONY	1963	270
DRUE ANN	1963	23
JACK PHARR	1963	184
BETTY LOU	1963	159
CATHY AND BARNEY	1963	62
PAN AMERICAN 20	1963	1246
JANUARY	1963	772
GEORGIA TECH	1963	609
EV-ANN	1963	516
COMMANDO	1963	356
NOLA	1963	1203
COURAGEOUS	1964	372
BARBARA	1964	115
LUCILLE	1964	973
INDEPENDENCE	1964	215
SASSY JANE	1964	1429
SHIP SHOAL	1964	1459
TERRY WALKER	1964	376
LYCO T.	1964	286
MISS SARAH	1964	1133
B AND J.	1 964	113
ADAK	1964	16
JANE MARLENE	1964	769
HULDA BEE	1 964	203
MISS LAURA	1964	1115
BARBARA JEAN	1 964	361
C.P. BAKER	1964	46
LIGHTNIN	1964	920
MISS TUCSON	1964	1140
BEVERLY ANN	1964	161
BLUE WATER I	1964	34
ALVIN J.	1964	51
SEA CONTRACTOR	1965	351
EASTBANK	1965	461
LIBBY ANN	1965	913
CAMPECHE	1965	237
BAROID EXPRESS	1965	18
MISS LIBERTY	1965	262
CHERAMIE NO.3	1965	319
G.I.JOE	1965	591
ONAWA	1965	258
CARL TIDE	1965	55
JIMBO	1965	4177

SHIP NAME	YEAR	REF. NO.
BAR PILOT	1965	17
CAVALIER	1965	73
BULL	1965	43
NELLY ROSE	1965	280
MISS PAT	1965	1128
PAMELA M	1965	1245
PRINCESS	1966	1303
FLIPPER TOO	1966	549
MINIMAX ELEVATOR	1966	254
ANDY MARTIN	1966	11
PLEIADES	1966	1205
MISS AMERICA	1966	1079
BETTY SCO.	1966	44
DESCO	1966	419
BAETTY SCA	1966	108
LITTLE RED	1966	226
OTIS IV	1966	1236
LILLIE MACK	1966	920
CHRIS ALAN	1966	327
MATAGORDA PILOT	1966	238
COMPASS STAR	1966	357
MR. B.	1966	343
DONCELYN	1966	96
CLARE ANN K	1966	330
JOANNE	1966	792
MALCOLM B. TOOMER	1966	241
REO SEAL	1966	1341
SADIE S.	1966	1405
SADIE S	1966	245
SUNRISE	1966	437
SANDRA F.	1966	1419
KATY SUE	1966	207
CAPT. CARL	1967	249
PAL-O-MINE	1967	1241
MRS LORINA	1967	1167
CAPT. CHARLES	1967	250
NAUGHTY GIRL	1967	279
BRAZOS VALLEY	1967	200
LEEWAY II	1967	264
HILL TIDE	1967	4162
TARAMBANA	1967	657
BLUE BONNET	1967	50
BECT NO.2	1967	129
LOUISE	1967	869
CAPT. Rd. SANDERS	1967	292
BONUS KEN	1967	202
MR. LUKE	1967	1165
ARTHUR J. ROTH	1967	89
CLEO SUE	1967	286
MISS SONORA LEIGH	1967	1135
CAPTAIN JOE	1968	51
GULF PRIDE	1968	657
MYSTERY II	1968	1172
MERMAID	1968	314
MARGO	1968	1017
CAPTAIN SCOTTY	1968	276
CAPTAIN STEVE	1968	53
UNKNOWN	1968	450
MR. MURPHY	1968	1166
WHIRLAWAY	1968	1640
JULI E	1968	204
LYCO XX	1968	235
TERRY ANO MIKE	1968	446
JULIE ANN	1968	834
LITTLE JOE	1968	951
JOHN R. COOK	1968	805

TABLE G-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
SAN JU THAD	1960	1416
MISS SUE	1968	1137
LITTLE GENERAL Iv	1968	946
ELLA	1969	486
MISS GEORGIA	1969	1103
LAOY VERNE	1969	252
BRETON ISLAND	1969	.
CARDINAL ELEVATOR	1969	202
BRETON ISLAND	1969	209
BIG DIPPER	1969	167
MISS FOUR HUNDRED	1969	1101
CORPUS LADY	1969	370
DELTA ELEVATOR	1969	412
POWHATTAN	1969	1298
SECO NO.2	1969	1449
MARGARET ANN	1969	1012
OEMAS C	1969	414
CAPT. 00N	1969	251
MYRTLE O	1969	1171
FRANCIS BRANDER	1969	574
LADY BETH	1969	802
CU 708	1969	83
ICE FLOE	1969	727
FOUR DS	1969	566
EL TIGRE GRANDE	1970	477
EL RANCHO	1970	476
KIM & KELLY	1970	860
FRIENDSHIP	1970	504
DEBBIE SUE	1970	402
L & M	1970	872
BIG ELEVATOR	1970	.
LEE TIOE	1970	904
CAPTAIN BILL	1970	263
BRG_1 18	1970	210
TAASINGE	1970	1531
BILL HOLLIS	1970	174
MERT	1970	1068
AMERICAN STAR	1970	54
OBSTRUCTION	1970	4153
BILLY & RICKY	1970	177
BALBOA	1970	111
KATHIE JUNE	1970	844
SEA WITCH	1970	1446
AIPLE_100	1970	26
WESTERN ACE	1970	.
KATHRYN JO ANN	1970	847
J W M II	1970	747
LADY OF THE SEA	1970	893
JOHN KURT	1970	803
MR. JEFF	1970	1163
GULF RANGER	1971	658
MISS GINGER	1971	1106
DEBORAH KAY	1971	406
MISS ANITA BRYANT	1971	1081
VERNON	1971	1607
SARAH ANN	1971	1426
P M J	1971	1239
DAISY MAE	1971	309
AURORA BORA	1971	101
FIVE KIDS	1971	545
LAFOURCHE	1971	096
FULL MOON	1971	506
ATHENA 2	1971	283
GLADYS BEA	1971	.
RICKY M	1971	1348
DORADO	1971	436

SHIP NAME	YEAR	REF. No.
WONDERFUL WORLD	1971	1665
DEBORA M	1971	404
GEORGIA MAE	1972	607
SKYLARK	1972	1471
MISS GEORGIA	1972	1104
FAIR WIND	1972	528
WHISPER	1972	1641
HAPPY FOUR	1972	438
BARBARA K.	1972	122
DE RAIL	1972	195
LISA GAIL	1972	272
SANDY BELLE	1972	1420
LAOY GAY	1972	884
MISS WANDA OENE	1972	1141
MOUETTE	1972	1154
J. STORM II	1972	749
YUCATAN	1972	1673
V A FOGG	1972	614
SMOKEY	1972	237
ST. LAURENT I	1972	1492
GULF KING XVIII	1972	649
SHIP ISLAND	1973	1458
LYCO V	1973	985
UNKNOWN	1973	232
GEMINI	1973	59T
RUBY GUY	1973	1388
KAMRON K.	1973	038
BELATRIX	1973	28
MISS JUDY ANN	1973	1113
'fish haven'	1973	3610
UNKNOWN	1973	190
UNKNOWN	1973	3610
GRACIE L.	1973	635
GRACIE L	1973	3646
JABE	1973	759
GULF KING_17	1973	650
NIEUWE MARKET	1973	1195
LYCO I	1973	3721
TYPHOON	1973	1590
POINT CHICOT	1973	1289
MOSES	1973	1153
CARIBE IV	1973	283
IJOYCE C.	1973	824
TERN	1973	1536
MISS TERRI	1973	1138
Q-5	1974	408
LORELEI	1974	963
BIG ED	1974	168
ATLAS	1974	
QUE_5	197A	1320
MARY ETTA	1974	1044
'liberty ship'	1974	3611
'liberty ship'	1974	3654
GIBSON GIRL	1974	616
'HELICOPTER'	1974	168
LU BELLE	1974	971
UNKNOWN	1974	3604
'fish haven'	1974	3621
'fish haven'	1974	3623
MISS ARANSAS	1974	1083
DRESSER VII	1974	451
GOINBROKE	1974	627
MISS MARY B	1974	1121
ATHENA III	1974	92
ALARICO	1975	30
LACY L.	1975	879

TABLE G-1 (CONTINUED).

SHIP MAME	YEAR	REF. NO.
ONE MULLET	1975	1227
PMI II	1975	1286
SABINE SEAHORSE	1875	1402
OBSTRUCTION	1975	235
PHANTOM	1S75	1273
CORAL SEA	1975	99
'liberty ship'	1975	3655
BETSY M	1975	3628
UNKNOWN	1975	181
PEGASUS	1975	1264
'liberty ship'	1975	3607
BOBBIE GAIL	1975	193
TOMMY BRAO	1875	1570
S P_2	1975	1490
ORLEANS	1975	1230
JUDY M	1975	831
MISS ANITA	1975	1080
HO HUM	1975	712
TERN	1976	1535
NONA GAIL	1976	1205
NONA GALE	1976	222
SUNDOWNER	1976	1516
JOYCE & JOE	1976	823
COLONELS LAOY	1976	35 1
MISS BESSIE M.	1976	1087
UNKNOWN	1976	183
CLAUDIA ELIZA G.	1976	341
BETTY G.	1976	157
VACA-DEL-MAR	1976	2607
OCEAN EXPRESS	1976	4184
NL_504	1976	1200
JIM DANDY	1976	784
CAR_2	1976	298
UNKNOWN	1976	312
GEORGE VANCOUVER	1976	275
HAT I	1977	684
CORA LEE	1977	361
GOLDEN DAWN	1977	620
ST. NICHOLAS	1977	1494
IMCO EXPLORER-2	1977	733
GULF KING_21	1977	651
BDCO NO.52	1977	124
'fish haven'	1977	3619
GUNSMOKE	1977	2670
THATS-A-MY-BOAT	1977	199
MADALINE GOFORTH	1977	998
UNKNOWN	1977	212
LIONEL HODGSON	1977	4191
BESCO	1977	41
CLEO C.	1977	344
LAMCO III	1977	898
THE BACHELORS II	1977	1545
GIGI IV	1977	3216
SHELL KEYS	1977	1455
LEE BROS	1977	902
NEW YORK	1977	1194
FIRST MATE	1977	227
STACY & JENNY	1977	1496
C JACK	1977	225
ENJOY	1978	293
CHARLES 11	1078	312
GOLDEN ISLE	1978	629
MARIAN S	1978	1019
FRANKIE E.	1978	578
UNKNOWN	1978	653
VIVIAN MARIE	1978	.

SHIP MANE	YEAR	REF. No.
CAPT 00C	1978	333
SEA WRESTLER	1978	1447
UNKNOWN	1978	1323
MISS TINA MARIE	1978	1139
REBEL HUSTLER	1978	1339
C-JACK I	1978	266
MISS LA MARQUE	1979	1114
GRACE C	1379	113
'liberty ship'	1979	3615
MICHELE JENENE	1979	1070
RITA M	1979	1356
JACK CRAWFORD	1979	760
UNKNOWN	1979	3614
ESCAPE MACHINE	1979	3720
MISS HELEN	1979	1109
HOT TUNA	1979	718
LARRY AND MABEL II	1979	900
LAOY O	1979	892
RANGER	1979	1332
ARTEMIS	1980	14
JOYNT EFFORT II	1980	827
'liberty ship'	1980	3613
INVADER	1980	658
JOHN PHILLIPS	1980	4139
LYNN I	1960	991
'fish haven'	1980	3609
CARMAR	19B0	2808
NORTH SEA	1980	2809
SANDPIPER II	1980	1418
AEOLUS	1980	20
UNKNOWN	1980	3242
CAPT MIKE	1980	247
F/V CRAWFISH	1981	3195
IJANE ANO IJULIE	1981	4182
LAURA	1981	165
SUNSHINE	1981	314
LAOY BRENOA	1981	158
OZARK	1981	263
UNKNOWN	1981	5S2
OAVANA	1982	4152
LADY NANCY	1982	161
BIG WHEEL	1982	3238
MISS ALINE	1982	2473
PROVIDENCE	1982	277
UNKNOWN	1982	3092
PROFILER 2	1983	275
EVELYN T	1983	94
TRANSWORLD 45	1983	334
UNKNOWN	1983	425
UNKNOWN	1983	451
CALYPSO LADY	1983	4154
LAVERNE HEBERT	1983	122
BARBARA D	1983	797
TRY ME	1983	3237
PBR 220	1983	266
UNKNOWN	1983	505
VIKING IV	1983	3236
DALE AND DAVID	1983	67
UNKNOWN	1984	345
PANKY	1984	265
MISS KECHIA	1984	214
OBSTRUCTION	1984	252
UNKNOWN	1984	4172
SCORPION	1984	4164
PENROD	1984	660
AMERICAN EAGLE "	1984	7

TABLE G-1 (CONTINUE).

SHIP NAME	YEAR	REF. No.
EAGLESCLIFF	1984	3327
WANDERING STAR	1984	3240
FLORENCE B.	1984	670
SANDY POINT	1985	296
CAPTAIN COOPER	1985	48
MARITIMER	1985	201
CAPTAIN TRUE	1985	4140
DAMN YANKEE	1985	652
UNKNOWN	1385	4161
LENORE	1985	4187
MICHAEL DAVID	1985	207
GEORGIA	1985	110
DERRICKS PRIDE	1985	70
UNKNOWN	1986	533
DEWEY	1987	490
OCEAN MAIO	1987	1213
PATRICIA B	1987	1252

APPENDIX H

Shipwrecks Found in State Waters

Table H-1.

Shipwrecks Found in State Waters.

SHIP NAME	YEAR	REF. No.
UNKNOWN	0	604
EL INFANTE	0	2860
UNKNOWN	0	537
UNKNOWN	0	531
UNKNOWN	0	544
M/V THUNDERBOLT	0	190
UNKNOWN	0	464
IVORY WRECK	0	225
UNKNOWN	0	607
UNKNOWN	0	497
UNKNOWN	0	588
UNKNOWN	0	408
SAUFLEY 00465	0	301
UNKNOWN	0	352
UNKNOWN	0	581
KENORICK DD612	0	149
UNKNOWN	0	445
UNKNOWN	0	578
LADY JANET	0	159
UNKNOWN	0	591
SANTA ROSA	0	408
UNKNOWN	0	442
GOLOENK	0	40
OBSTRUCTION	0	238
UNKNOWN	0	514
OBSTRUCTION	0	247
FISH REEF	0	99
UNKNOWN	0	499
UNKNOWN	0	401
OLGA	0	257
UNKNOWN	0	494
UNKNOWN	0	444
UNKNOWN	0	589
UNKNOWN	0	553
UNKNOWN	0	611
UNKNOWN	0	434
ORION	0	261
UNKNOWN	0	590
EAGLE BOAT	0	85
UNKNOWN	0	415
UNKNOWN	0	457
UNKNOWN	0	513
UNKNOWN	0	380
UNKNOWN	0	2
UNKNOWN	0	610
UNKNOWN	0	383
UNKNOWN	0	353
UNKNOWN	0	517
LITTLE DAVID	0	178
UNKNOWN	0	1
BAGS	0	17
OBSTRUCTION	0	234
UNKNOWN	0	189
UNKNOWN	0	586
ZALOPHUS	0	634
UNKNOWN	0	381
UNKNOWN	0	484
UNKNOWN	0	648
UNKNOWN	0	492
UNKNOWN	0	514
CINDY	0	649
UNKNOWN	0	491
UNKNOWN	0	488
SEA GAL	0	193
EMPRESS ANN	0	93
MADAME QUEEN	0	184

TABLE H-1 (CONTINUE).

SHIP NAME	YEAR	REF. NO.
UNKNOWN	0	354
UNKNOWN	0	502
UNKNOWN	0	487
BRICK WRECK	0	68
IRON BALLAST WRECK	0	222
UNKNOWN	0	494
UNKNOWN	0	416
KIM-G	0	153
ELLA MACVONA	0	88
UNKNOWN	0	2919
UNKNOWN	0	3055
E E SIMPSON	0	82
UNKNOWN	0	3141
YANKEE CLIPPPER	0	630
UNKNOWN	0	556
UNKNOWN	0	493
FOUR ACES	0	103
LITTLE DAVID	0	177
UNKNOWN	0	530
TARGET	0	677
UNKNOWN	0	464
UNKNOWN	0	3734
BRIDE OF LORNE	0	454
ANNA PEPINA	0	458
UNKNOWN	0	1772
UNKNOWN	0	48 t
FORTANIA	0	102
UNKNOWN	0	523
WADDON	0	467
PEGGY G	0	266
UNKNOWN	0	3640
UNKNOWN	0	3518
UNKNOWN	0	3593
MANHORTON	0	196
JOY	0	145
MARION D	0	200
UNKNOWN	0	570
MARY ROSE	0	203
UNKNOWN	0	577
UNKNOWN	0	387
UNKNOWN	0	397
UNKNOWN	0	394
UNKNOWN	0	444
UNKNOWN	0	574
UNKNOWN	0	528
MISS. PAT	0	216
BAYOU BELLE	0	25
UNKNOWN	0	418
DOLLY DIMPLES	0	72
UNKNOWN	0	503
GEORGIA PEACH	0	111
UNKNOWN	0	490
RIG TENDER	0	286
UNKNOWN	0	441
UNKNOWN	0	483
JUDY	0	146
UNKNOWN	0	475
UNKNOWN	0	453
SCI NO. 5	0	302
UNKNOWN	0	485
UNKNOWN	0	391
UNKNOWN	0	562
UNKNOWN	0	364
DONCELN	0	75
CAPTAIN HARRY	0	51
ELLAMAE VAUGN	0	89

SHIP NAME	YEAR	REF. NO.
PORTLAND	0	372
STRANGER	0	436
UNKNOWN	0	535
WRECKAGE	0	629
UNKNOWN	0	546
UNKNOWN	0	498
UNKNOWN	0	510
UNKNOWN	0	363
JOHNNY K	0	142
UNKNOWN	0	474
UNKNOWN	0	583
TERRY ANO MIKE	0	321
LITTLE GIANT	0	181
UNKNOWN	0	2658
THREE SISTERS	0	328
CLIPPER	0	88
ARKANSAS	0	31
UNKNOWN	0	46%
ACADIA	0	5
PODUNK QUEEN	0	371
UNKNOWN	0	412
SAINT MICHAEL	0	407
JIMBO	0	225
CAPTAIN PETE	0	53
AMERICAN	0	18
TAMAULIPAS	0	440
MASCOT	0	307
SEA BIRO	0	303
VIOLET GLADYS	0	619
GENERAL CLARK	0	175
GULF RAIDER	0	191
BO K	0	52
WAGON TRAIN	0	623
MATAGORDA PILOT	0	308
GENERAL CLARK	0	109
UNKNOWN	0	422
UNKNOWN	0	218
WILDCAT	0	530
JIMBD	0	226
CAROLINE	0	69
FLORENCE BERNICE	0	164
BIG DADDY	0	33
SAN ANTON	1521	397
UNKNOWN	1528	426
UNKNOWN	152B	441
UNKNOWN	1528	428
UNKNOWN	1549	490
VISITATION	1550	556
SANTA MARIA DE ICIAR	1554	414
SAN ESTEBAN	1554	411
ESPIRITU SANTO	1554	148
VARGARA'S BOAT	1554	518
UNKNOWN	1565	535
NRA. SRA. DEL ROSARIO	1593	312
UNKNOWN	1595	517
SANTA MARGARITA	1595	382
SHOT WRECK	1600	419
BRONZE CANNON WRECK	1600	75
UNKNOWN	1621	534
NUESTRA SEN DELROSARIO	1622	340
LA MARGARITA	1622	235
UNKNOWN	1622	463
JESUS SEN DEL ROSARID	1622	231
JESUS Y NUESTRA ROSARIO	1622	210
NUESTRA SEN DE ATOCHA	1622	339
CAPITANA	1623	63

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. ND.
UNKNOWN	1630	433
UNKNOWN	1634	427
UNKNOWN	1643	436
UNKNOWN	1643	431
UNKNOWN	1677	478
LA BELLE	1685	248
UNKNOWN	1685	438
NAO	1688	315
UNKNOWN	1688	483
HENRIETTA MARIE	1698	202
UNKNOWN	1700	538
UNKNOWN	1700	475
WALKER KEY WRECK	1700	560
UNKNOWN	1700	515
UNKNOWN WRECK	1700	543
WRECK #12	1700	577
UNKNOWN	1 700	458
UNKNOWN	1700	512
SAINT ANTOINE	1705	
HERRERA WRECK	1715	209
SAN PEDRO	1717	345
EL CAPTAIN	1717	110
LA BELLONE	1725	
BRIGANTINE “OF DUCLOS	1725	
LE SAINT LOUIS	1733	
SAN JOSE OE LAS ANIMAS	1733	403
CAPITANA	1733	62
CHAVEZ	1733	95
LOS TRES PUENTES	1733	266
NS BELEM SAN ANTONIO	7733	334
NS BELEM JUAN BAUTISTA	1733	333
NS CARMEN SAN ANTONIO	1733	335
EL PODER OE DIOS	1733	142
EL LERI	1733	141
EL POPER OE 010S	1733	143
NS ROSARIO SAN ANTONIO	1733	337
FLORIDANA	1733	166
SAN FRANCISCO DE ASIS	1733	401
NS ANGUSTIAS SAN RAFAEL	1733	331
NS ROSARIO SAN FRANCIS	1733	338
SAN FRANCISCO	1733	378
SAN RAFAEL	1733	405
GALLO INDIANA (POSS.)	1733	177
WALKER KEY WRECK	1733	453
SAN FERNANOO	1733	400
EL GRAN PDOER OE DIOS Y	1733	140
SAN IGNACIO	1733	379
SAN FELIPE	1733	399
LA MARGUERITE	1737	
UNKNOWN	1737	
NAFFAW	1741	308
FURTE	1742	175
H.M.S. TYGER	1742	195
BILLANDER BETTY	1744	61
H.M.S. LOOE	1744	1s3
SWIVEL GUN SITE	1750	437
QUEEN ANNE	1752	373
GREENVILLE PACKET	1765	186
GENERAL CONWAY	1766	180
UNKNOWN	1766	498
EL NUEVO CONSTANTE	1766	119
UNKNOWN	1766	470
UNKNOWN	1766	486
ANNA THERESA	176S	31
SAN ANTONIO	1760	373
UNKNOWN	1770	504

SHIP NAME	YEAR	REF. NO.
UNKNOWN	1770	503
UNKNOWN	1771	466
RHEE GALLEY	1774	378
ANN & ELIZABETH	1774	28
UNKNOWN	1775	405
SANTISIMA CONCEPTION	1775	384
UNKNOWN	1776	471
LA CARAQUENA	1776	234
ROBERT	1777	
UNKNOWN	1778	495
MARY	1778	284
SARAH & ELIZABETH	1778	409
FRANCESA	1781	144
UNKNOWN	1782	461
H.M.S. MENTOR	1782	194
EVENLY	1788	153
FLY	1789	167
UNKNOWN	1790	496
LIVELY	1791	263
LOVELY ANN	1792	270
GENERAL CLARK	1793	179
CATHERINE GREEN	1794	91
NOAH'S' ARK	1795	327
FLORA	1798	163
HMS FOX	1799	183
GRANITE WRECK	180Q	184
UNKNOWN	1 Boo	465
UNKNOWN	1600	462
BRONZE WRECK	1800	76
UNKNOWN	1800	536
HECTOR	1800	200
GOOD HOPE	1800	183
IRON BALLAST WRECK	1800	221
FISCHER ROBINS CLAUSE	1800	160
SCHOONER WRECK	1800	410
HMS MELEAGER	1801	185
EAGLE	1801	112
BRITANNIA	1 803	73
CALLIOPE	1804	82
ANDROMACHE	1805	24
PROVIDENCE	1805	371
MARIA	1806	261
CABINET	1811	80
EARL BATHURST	1811	114
ORION	1812	350
AMERICANO	1814	19
INTREPIDO	1814	216
JERUSALEM	1815	229
WATT	1815	565
VOLADOR II	1815	558
ROSA	1815	355
SANTA ROSA	1815	348
MAGDALEN	1816	274
COSSACK	1816	113
SIR JOHN SHERBROKE	1816	394
EUROPA	1817	151
MARQUIS DE POMBAL	1817	282
MERRIMACK	1817	294
UNNAMED LAFITTE	1818	
QUEBEC	1818	372
SOLWAY	1818	422
BETSEY	1818	59
ACASTA	1818	5
HIBERNIA	1818	182
UNKNOWN	1818	472
SANDWICH	1819	406

TABLE H-1 (CONTINUE).

SHIP NAME	YEAR	REF . ND.
ANIE OF SCARBOR	1819	27
BARILLA	1819	49
BRIG	1819	70
MISSISSIPPI	1821	286
COSMOPOLITE	1821	112
GASPARILLA	1821	138
MISSISSIPPI	1821	286
NAVIGATOR	1821	302
MARGARET ANN	1822	259
ALLIGATOR	1822	21
U.S.S. ALLIGATOR	1822	456
ANN OF LONDON	1822	29
UNKNOWN	1822	506
FRANCIS & LUCY	1822	170
LADY WASHINGTON	1822	248
MARGARET ANN	1822	259
PARKER & SONS	1823	325
FRANKLIN	1823	171
LEOPARD	1823	255
INTREPIDO	1823	193
THEODORE	1824	444
POINTE-A-PETRE	1824	366
CERES	1824	92
SARAH	1824	385
JOHAN CARL	1825	233
REVENGE	1825	377
MUNROE	1826	292
NANNU	1828	314
VIGILANT	1828	551
MISSISSIPPI	1829	302
ELIZABETH	1829	137
GENERAL LAFAYETTE	1829	176
VINEYARD	1830	393
UNKNOWN	1830	477
SPLENDID	1831	427
AMULET	1831	22
MT. HOPE	1831	306
TOI SON	1831	450
HENRY	1831	203
EXERTON	1831	155
DUMFRIES	1831	111
MOUNT VERNON	1831	289
KLEEBURG	1831	245
EMELINE	1832	141
CORDENA	1834	106
SEALION	1834	423
UNKNOWN	1834	504
PHEONIX	1834	366
GALAXY	1835	176
VERSAILLES	1835	448
ELIZA ANN	1835	135
AMERICA	1835	17
ELIZABETH	1835	136
SPARTACUS	1835	430
IZARD	1836	201
FLORA	1836	162
TALLAHASSEE	1836	439
AMERICA	1836	17
LOD I	1836	276
HALCYON	1836	196
BILLOW	1837	62
CHAMPION	1837	76
BELLE	1837	40
TOM TOBY	1837	456
FLASH	1837	139
INVINCIBLE	1837	196

SHIP NAME	YEAR	REF. No.
BRUTUS	1837	55
FLASH	1837	161
YELLOWSTONE	1837	407
LOUISIANA	1837	279
BONITA	1837	53
JULIUS CAESAR	1837	241
JULIA E. MILLETS	1837	227
MOTTO	1838	268
CONSTITUTION	1838	101
ALBERT	1839	10
POACHER	1840	365
UNIDENTIFIED	1840	457
BILLY BOWLEGS	1840	63
BILLY (BOWLEGS) ROGERS	1840	30
RODNEY	1840	394
UNKNOWN	1841	481
LAMPLIGHTER	1841	237
PLUTUS	1841	60
EMBLEM	1841	17
NAPOLEAN	1841	48
ALASCO	1842	9
PEGUOT	1842	359
CUBA	1842	11
AXIS	1842	46
CAROLINE	1842	90
KEY WEST	1842	31
1s1s	1842	223
NEW YORK	1842	52
RUDOLPH GRONING	1842	360
MARION	1842	41
JAMES ADAMS	1842	30
LADY ANN	1842	32
LAOY MUNROE	1842	33
ELIZA	1842	16
FARMER'S RETURN	1842	157
ANSON	1843	32
COL. T SHEPPARD	1843	104
IVANHOE	1843	27
PILGRIM	1843	59
REBECCA	1843	376
COUNSELOR	1843	10
ROBERT FULTON	1843	383
RELIEF	1843	61
EMBLEM	1843	18
SUCCESS	1844	71
ATHALIA	1844	40
ROSELLA	1844	64
WELLINGTON	1844	567
SELECT	1844	416
ZOTOFF	1844	468
STATIRA	1844	70
NEW HANOVER	1844	50
RIENZI	1845	62
LADY BYRON	1845	250
DAYTON	1845	111
MARY WALKER	1845	43
IRIS	1846	26
PERRY	1846	58
MORRIS	1846	46
METAMORA	1846	44
NAPOLEAN	1846	47
OLIVE & ELIZA	1846	348
ALIDA	1846	2
Commissary	1846	107
MELEMORA	1846	292
H.W. STAFFORD	1846	196

TABLE H-1 (CONTINUE)).

SHIP NAME	YEAR	REF. No.
LAFAYETTE	1846	34
GENERAL WILSON	1846	22
EXCHANGE	1846	19
OLIVE AND ELIZA	1846	53
DELIA	1846	14
EDWARD TILLITT	1846	15
MONMOUTH	1846	321
POTOMAC	1846	305
S.G. MYRES	1846	65
AUGUSTA	1846	14
OREGON	1846	54
RIGHT BOWER	1846	63
URSULA	1846	76
WARSAW	1846	79
MARY MARSHALL	1846	306
ORLEANS	1846	55
TWO FRIENDS	1846	75
SEA	1846	68
COL HARNEY or HARVEY	1846	89
FREDERICK	1846	145
LEO	1846	36
DEFIANCE	1846	12
JOHN HOWELL	1847	237
AUGUSTA	1847	44
COLONEL YELL	1847	94
VIRGINIA	1847	522
L A M A	1847	255
HUNT E R	1847	204
COFFIN	1847	89
GIRAFFE	1847	179
MONROE	1847	322
MARY EMMA	1847	303
CANTON	1848	60
AID	1848	9
W.C. PRESTON	1848	525
LAUREL	1848	259
NANCY W. STEVENS	1849	310
EMILY	1849	127
SAMUEL M. WILLIAMS	1849	410
BROWNSVILLE	1849	41
UNKNOWN	1850	469
NEW ORLEANS	1850	324
UNKNOWN	1850	511
SYLPHIDE	1850	438
IRENE	1850	178
E.A. OGDEN	1850	
ENVOY	1850	115
COLONEL CROSS	1850	90
GALVESTON	1851	137
WILLIAM ANO MARY	1851	533
COMMERCIAL	1851	88
WILLIAM PENN	1851	534
TOM BROWN	1851	455
MARIA BURT .	1851	243
TOM BROWN	1851	420
PALMETTO	1852	355
ALBANY	1852	10
NANI OPE	1852	296
METEOR	1852	251
UMPIRE	1852	462
PERSERVERENCE	1853	362
STAR STATE	1853	365
FARMER	1853	123
UNKNOWN	1853	4a9
UNKNOWN	1853	490
HARRIET ANO MARTHA	1854	198

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
NICK HILL	1854	335
TARTAR	1855	412
UNKNOWN	1855	483
S.S. FLORIDA	1656	364
PACIFIC	1857	322
OPELOUSAS	1857	317
MAJOR A. HARRIS	1857	240
LOUISIANA	1857	231
MARTHA GILCHRIST	1858	267
UNKNOWN	1058	503
GRAPESHOT	1858	157
GRAPE SHOT	1858	189
SOUTH CAROLINA	1859	358
BETTY POWELL	1859	25
CUEA	1859	97
LIZZIE LAKE	1859	247
CERRO GORDO	1860	74
SOUTH CAROLINA	1860	399
WILLIAM C. YOUNG	1860	421
FINLAND	1861	138
AID	1861	12
JUDAH	1861	225
ROYAL YACHT	1861	358
REINDEER	1861	385
HAVANA	1862	170
HELEN	1862	172
ADVOCATE	1862	9
DAYLIGHT or DELIGHT	1862	101
GARONNE	1862	148
EXPRESS	1862	134
OSCEOLA	1S62	320
COLUMBIA	1862	95
MARY AGNES	1862	298
IOA	1863	189
MARY IJANE	1863	276
POWERFUL	1863	469
CAROLINE GERTRUDE	1863	67
USS PREBLE	1863	446
NATHANIEL TAYLOR	1863	300
FOX	1863	143
TEXANA	1863	414
MIST	1863	287
HELANA	1863	171
SARAH BLADEN	1863	386
CONCORDIA	1863	92
PUSHMATAHA	1863	341
WESTFIELD	1863	459
NEPTUNE	1863	304
·JANE	1863	206
JOHN F. CARR	1863	213
BAGLEY	$863	36
GENERAL C.C. PINCKNEY	1863	174
LAOWING	1863	249
ALICE AND MARY	1863	14
MORNING STAR 11	1863	267
GENERAL FINNEGAN	1864	151
ETTA	1864	131
MATAGORDA	1864	277
ROSINA	1864	396
CATHERINE HOLT	1864	70
LOUISA	1864	251
IKE DAVIS	1864	208
UNKNOWN	1865	464
SORT	1865	3 9 7
FLORIDA	1865	140
ATLANTA	1865	32

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
USS IDA	1865	444
UNKNOWN	1865	550
LE COMPTE	1865	262
UNKNOWN	1865	507
CSS LE COMPT	1865	86
LECOMPT	1865	241
WILL-D-THE-WISP	1865	531
UNKNOWN	1865	493
DENBIGH	1865	115
GRANITE CITY	1865	188
LOUISA	1865	278
JAMES DUCKETT	1865	218
ORIZABA	1865	345
PELICAN	1865	360
TERESITA 24721	1865	445
JOHN BULL	1865	229
TAMPICO	1865	441
MEXICO	1865	252
PAMPERO	1866	324
REBECCA BARTON (21530)	1866	375
SOPHIA	1866	424
NATCHEZ	1866	278
ELLA	1866	121
POTOMSKA	1866	306
RIO GRANDE	1866	393
MONTEZUMA	1866	325
NEW MUNNERLYN	1867	322
SUN FLOWER	1867	368
ALICE M.	1867	19
PRINCE ALBERT	1867	374
ADMIRAL FOOTE	1867	8
YOUNG AMERICA	1867	408
ANTONIA	1867	29
TERDOO	1867	444
PRIMERO	1867	373
EDITH	1867	117
EMERALD	1868	126
GOVERNOR MORTON	1868	146
BELVIDERE	1868	42
SELMA	1868	424
PHILADELPHIA	1868	369
BRAVO	1868	56
NORDCAP	1869	337
GLADIATOR	1869	180
MUTTER SHULTZ	1870	307
HONDURAS (10524)	1670	213
MARIA FERGUSON	1870	263
LOUISBURG	1870	269
SENECA	1870	391
EUTERPE	1870	117
BARNETT	1871	50
FANNY	1871	122
NOR'WESTER	1872	310
SONORA	1872	423
JULIA	1872	226
ELLA MAY (8371)	1872	145
ECLIPSE 8665	1872	127
ECLIPSE	1872	116
HUMTREAZ	1873	188
MARY E. FORSYTHE	1873	248
MATTIE	1873	310
S.J. LEE	1873	333
ETHEL	1874	149
J.S. SELLERS 75126	1874	215
RATTLER 56328	1874	382
SAINT MARY	1874	405

SHIP NAME	YEAR	REF. No.
MOUNTAIN HOME	1875	290
ERA	1875	129
WILLIAM M. JONES	1875	569
HENRY J. MAY	1875	204
MATTIE	1875	311
EDITH BELLE NASON DOVER	1875	129
ECLIPSE 8665	1875	128
EMORY	1875	144
COMMODORE MORBIT	1875	99
CAROLINE	1875	68
ANNETTA	1875	26
ALICE	1875	13
LAKE AUSTIN	1875	254
FLOUNDER 9547	1875	167
TIDAL WAVE 24882	1875	453
STAR OF THE SOUTH 23306	1875	435
SHELL FISH	1875	425
ROYINIA	1875	398
PHEONI X	1875	367
PROUTY	1875	377
DELMORE	1875	113
CORA BICKFORD 5345	1875	104
CITY OF WACO	1875	82
DESPERAOO 6741	1875	117
WITCH OF THE WAVE	1875	.
PEEDIE	1875	327
MAGGIE	1875	.
MARY 1876	1875	268
JESSIE	1875	224
GODFREY KEEBLER	1876	
JALAPA	1876	204
MAGDALA	1876	
ST. MARY	1876	433
MARY	1876	297
PROTECTOR	1877	370
EMILIE	1877	
OCEAN QUEEN	1877	342
MEZZIE	1877	295
MEGGIE or MEZZIE	1877	280
TWO SISTERS	1877	
HENRY MEARCY	1878	176
BERLINDA	1878	
BONNIE AOVENTURE	1879	49
AURORA	1879	34
PEARL RIVERS	1879	357
SEABIRD	1880	387
BRAVO 2682	1880	57
BRAISTED	1880	55
ANNETTE 1384	1880	27
MARY	1880	
AMEDIO FIRST	1880	
LAUREL	1880	
BRAVO	1880	50
CARRIE THOMAS	1880	59
JOSEPH BAKER	1881	239
TOLOMEO	1881	451
DIRIGO	1881	105
HERMES	1881	180
CONGO STATE	1881	100
DANIEL GOOS	1881	
R.B. GOVE	1862	343
RELIABLE #2	1882	349
UNKNOWN	1882	477
UNKNOWN	1882	476
UNKNOWN	1882	481
UNKNOWN	1882	500

TABLE H-i (CONTINUED).

SHIP NAME	YEAR	REF. Ho.
ZENOBIA	1882	543
RAMYREZ	1882	381
TEX MEX	1882	448
TWO MARYS 24313	1882	461
ABEONA	1882	.
DAY BREAK	1883	100
LAURA R. BURNHAM	1883	.
LAURA R. BURNHAM 15962	1883	258
ANNIE LAURA	1884	
ALICE	1884	17
GUTENBERG	1885	189
GUTENBURG	1885	161
MARY E. CLARKE	1885	272
PAT CHRISTIAN	1885	
ORIENT	1885	
CHARLES R. CAMPBELL	1886	94
C.H. FROZIER	1886	58
JANE EMERSON	1886	
LITTLE SIMMS	1886	.
BUFFALO BILL	1886	58
ORANZOFF	1886	343
S.W. PERRY	1886	366
LIVONIA PERKINS	1886	
ELLA ELLIOT	1886	139
GRANFOS	1886	187
FLOWER OF FRANCE	1886	141
ARTHUR	1887	38
FREDDIE L. PORTER	1887	173
JOSHUA H. MARVELL	1887	240
SEBULON	18B7	389
SAMUEL MACMANEMY	1887	396
AMANDA	1887	16
BRIDE OF LORNE	1887	51
ARANSAS 105749	1887	30
JOSEPHINE	1887	202
O'JENNINGS GILL	1887	340
LUISITA	1887	282
PRINCE UMBERTO	1888	368
WILLIAM TITTAMER 26511	1888	573
small boat	1888	.
UNKNOWN	1888	467
CEPHAS STARRET	1888	72
CLEOPATRA	1888	
LAUREL	1888	
SEA GULL	1888	.
HENRIETTA	1888	200
SEMINOLE	1888	
ADALAID BAKER	1889	6
ADELAIDE BAKER	1889	7
TRUE BRITON	1889	423
CARL O. LOTHROP	1889	65
ELLA B.	1889	
sailboat	1889	.
URBANO	1889	545
small boat	1889	
ALPHONSINE	1889	23
EBBA	1889	115
HAAVUND	1889	160
PRINCE LUCIEN	1889	307
EBBA	1889	106
ELLEN	1889	
T.F.P.	1889	
ABBIE DEES	1889	
HENRIETTA	1889	
LILLIE G.	1889	
KELVIN	1889	

SHIP NAME	YEAR	REF. NO.
VIOLA	1889	
catboat	1889	
small boat	1889	
Ad. PERKINS	1889	
ROBERT TEMPLETON	1889	
BARGE #13	1889	37
Ad. PERKINS	1869	
ADELIA	1889	
C.H. MOORE	1889	
FLORA WOODHOUSE	1889	
TERESA	1889	
STAR	1869	.
EASTERN LIGHT	1890	487
DOMENICO	1890	95
CASTILLA	1890	
GOOO INTENT	1690	
MOUNTAIN GIRL	1890	269
ERL	1891	
WATESKA	1891	45s
H.A. DEWITT	1891	191
JOSEPH BAKER	1691	220
DEXTER CLARK	1891	
AMICUS	1891	
HATTIE G. MCFARLAND	1891	
BERTHA DRAHEIM	1891	
LIVINGSTONE	1691	.
ALFHILD	1891	6
FRANK HITCHCOCK	1891	.
COQUETTE	1891	81
MAUD McLANE	1891	
SHANNON	1892	392
MARY JANETTE	1892	
LILLY	1892	269
FAIR PLAY	1892	155
LIBERTY	1892	
LIBERTY 14998	1892	267
ARCADIA	1893	31
CARMALITA COMPOSITE	1893	88
OCTAVIA	1893	
ERA	1893	
SANTA MARIA	1893	
ANNIE E.B.	1893	
F.W. ELMER	1893	
ELIZA B.	1893	120
JOE WEBRE	1893	211
JOSIE	1893	236
BRANDON	1894	
MARIA	1894	
CATHRINE	1894	
INGRID	1895	
BEATRICE	1895	36
BEATRICE McLEAN	1895	
WALTER D. WALLETT	1895	454
JENNIE WOOO	1895	
AGNES	1895	10
C. BRAISTED	1895	59
SCANDINAVIAN	1895	417
ALFREO ANO SAMMIE	1895	16
SHELTER ISLAND	1896	418
ANNA	1096	
MABEL TAYLOR	1896	
ANNA PEPPINA	1896	
FLORA S. 120274	1896	163
ANDREW BOWDEN	1896	21
CLYDE	1897	85
CLYDE (5001)	1897	103

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
AMELIA	1897	
ORLINA	1897	346
COLONEL RUFUS INGALLS	1897	93
CADICE	1898	
HENRY STANBERY	1898	177
OSMOND	1898	
BUTESHIRE	1898	
SPORT	1898	431
GLAD TIDINGS	1899	153
GRACE ANDREWS	1899	
JAMES BAIRD	1899	
AMELIA	1899	16
MYSTERY	1899	330
COPENHAGEN	1900	108
UNKNOWN	1900	533
LIDA FRANCIS	1900	244
IJOHN W. SMART	1900	219
NELLIE M. SLADE	1900	
STEEL WRECK	1900	430
CUMBERLAND	1900	
JENNIE S. BUTLER	1900	222
MARY JANETTE	1900	304
EAGLE NO. 1	1900	126
MARY LORENA	1900	305
J.M. McINNIS	1900	
BELLE	1901	37
CHARLES E. BALCH	1901	.
S.J. DICKSON	1901	363
ELLEN	1901	140
LA PLATA	1902	
SILAS	1902	426
NINEVAH	1903	1199
EVA I. SHINTON	1903	133
MARGARET WARD	1903	
THOMAS	1903	1556
KITTY HORR	1904	867
LENA R. STORER	1904	
BIANCA CASANOVA	1904	
LUZON	1904	283
MOUNT PLEASANT	1905	1155
PARGO	190s	1249
VOLUNTEER	1 905	1623
EAGLE	1905	132
A. HAYFORD	1905	2
MARGUEDONA	1905	260
NORTHERN EMPIRE	1905	
LOUISE	1905	229
ANNIE ROOT	1905	77
OCTAVIA	1905	1216
ZILLAH	1905	1675
EDITH L. ALLEN	1908	136
SIDNEY	1906	1463
PALM	1906	1243
RACE	1906	1325
MOCCASIN	1906	1147
ADAM W. SPIES	1906	5
VANDALIA	1906	1602
PELICAN	1908	329
S.0. CO. NO.90	1906	1397
MARIETTA	1906	1024
WM. H. WARREN	1906	1664
WILLIAM H. WARREN	1906	
ANGELO AMANDA	1906	2?
CAMPBELL	1906	
OLIVARI	1906	
MARIE	1906	

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
MINERVA	1906	297
HILARY	1906	708
UNKNOWN	1906	1490
EDGAR RANDALL	1906	469
GAMMA	1906	595
EMMA	1906	.
LILA	1906	822
GUSSIE	1906	155
AGNES	1906	23
OLIVIA	1906	1224
MARY GRAY	1 906	1046
MAGDALENE	1906	
HERCULES	1906	
FALCON	1906	
DAISY	190%	
STARKE	1906	1499
BAUNEN	1906	
FLUORINE	1906	129
MARGRETTE B.	1906	1016
HOO HOO	1906	172
TROJAN	1906	
MANATEE	1907	1009
DASH	1907	396
IRENE	1907	738
AVANTI	1907	
FAWN	1907	535
FLORENCE WITHERBEE	1907	164
D.H. MORRIS	1907	
CLARKE OIL TANK NO. 3	1907	
UNKNOWN	1908	3117
EUGENE BATTY	1908	512
WAVE	1908	566
LIBERTY	1908	915
IDA	1908	728
MAUD SPURLING	1908	.
GEORGE	1908	601
BRUCE	1908	42
FEVUE ARLANO	1908	539
TRAVELER	1908	45-1
PEERLESS	1909	328
WANOERER	1909	562
SYBIL	1909	
MANAGUA	1909	1 008
EMMA ELIZA	1909	501
MEDFORD	1909	
NETTIE J.	1909	1180
NOAL	1909	1201
ROSEBUD	1909	1379
S.H. WOODBURY	1009	1396
REAPER	1909	1337
S.R. MALLORY	1909	1399
UNDINE	1909	1593
ADDIE AND NORMAN	1909	18
ADA	1909	14
AMY	1909	58
CARMEN	1 909	286
BRAGANZA	1 809	65
EMPIRE	1s09	504
ELIZABETH ANN	1909	483
FLORIDA	1909	555
ETHEL	1909	510
IMPULSE	1909	734
JUNIATA	1909	835
KATE DAVIS	1909	841
HAVANA	1909	686
GERTRUDE	1909	613

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
KATE	1909	840
GLANCE	1909	621
FREDDIE W. ALTON	1909	174
DAVY CROCKETT	1909	117
ELLEN M. ADAMS	1909	124
NANNIE C. BOHLIN	1909	1177
VIVIAN	1909	1619
IRA	1909	198
CLEOPATRA	1909	345
SUN	1909	433
ST JOSEPH	1909	
CUBA	1909	376
HASSIA	1909	
NURE	1909	
ALL HOPE	1909	39
CLEMENTINE	1909	342
HENRY WESTON	1909	698
MARGARET KENNEDY	1909	1014
MARY AGNES	1909	1035
GANT	1909	
BONITA	1909	199
LONDON	1909	960
GEORGIA H.	1909	606
KATE FEORE	1909	842
JIMMIE	1909	786
EDWARD T. STOTESBURG	1910	474
MAY FLOWER	1910	1058
UNKNOWN	1910	509
VIRGINIA	1910	450
HEARTSEASE	1910	689
LILY WHITE	1910	929
FLORIDA	1910	554
HJALMAR	1910	211
HERMANN OELRICHS	1910	703
WI LHENA	1910	1651
WILLENA	1910	461
A.A. FLETCHER	1910	8
TRIUNFO	1910	.
HARRY CAGE	1910	167
ARKADIA	1910	83
WILLIE WALLACE	1911	1656
WM. EDENBORN	1911	404
RUTH A.	1911	362
WINFIELD S. SHUSTER	1911	575
BERTHA RITTER	1911	143
WATER BOY	1911	1636
DREDGE HESTER	1911	103
MARY ELIZA	1911	285
ORONO	1911	351
FRANCES AND LOUISA	1911	570
E. HEMPSTEAD	1911	456
BELLE	1s11	39
CLARKE OIL TANK NO.2	1s11	340
LIBBIE SHEARN	1s11	266
WILLIAM R. WILSON	1912	401
JOLLY TRAMP	1912	816
EMERALD	1912	497
10LA	1912	218
FREDDIE HENCHON	1912	146
FREDDIE HENCKEN	1912	
WAUL	1912	396
ELZADA	1912	.
FLORENCE	1912	551
GERTRUDE SUMMERS	1912	615
UNKNO UN	1913	505
CLIFFORD N. CARVER	1913	83

SHIP NAME	YEAR	REF. NO.
PENDELTON BROTHERS	1913	1269
CARRIE B. WELLES	1913	294
NED. P. WALKER	1913	1182
LAURA L. SPRAGUE	1913	217
ALMIRA	1913	47
THOMAS S. DENNISON	1913	448
D.L. TRAFTON	1913	384
HOPPER	1913	173
CLARA IDA	1913	335
GENERAL C.B. COMSTOCK	1913	173
HELEN STORY	1913	168
MARKAB	1914	1031
PLANTER	1914	334
EDNA LOUISE	1914	471
IRENE ALBURY	1914	739
AMELIA	1914	52
HENRIETTA J. POWELL	1914	696
J.D. ELLISON	1914	
NELLY	1914	1184
EVANGELIZE	1914	519
MADELEINE	1914	237
MADELEINE	1914	
MARY ELLEN	1914	1043
IRIS	1914	740
FIDO	1914	
IJOHN C WHILDIN	1915	212
JOHN G. WHILDIN	1915	235
MAUDE B. KRUM	1915	287
CLARA P. SEWALL	1915	336
J.B. RABEL	1915	
JOHN W. OANA	1915	
UNKNOWN	1915	50s
SAM HOUSTON	1915	338
SAN JACINTO	1915	343
THOMAS J. CARROL	1915	1558
DAISY	1915	388
DORA ALLISON	1915	99
L.P. FEATHERSTONE	1915	214
GLIDE	1915	623
NETTIE FRANKLIN	1915	281
LEONE	1915	909
REDFISH	1915	1343
LITTLE DORA	1915	943
CLARA	1s15	334
HARRY	1915	681
SAM HOUSTON/SAN JACINTO	1915	370
OSCEOLA	1915	1231
LITTLE FREDDIE	1s15	945
MAROWIJNE	1915	247
LILLIAN	1915	S25
DORA ALLISON	1915	
SANTAIGO	1916	66
KATHRYN B	1916	846
NORWICH	1S16	1210
AV10	1916	.
JOHN M. KEEN	1916	238
POL RDS	1S16	1290
MISCHIEF	1816	1078
DOROTHY	1916	10Q
CHAMPION	1916	310
MARY G. DANTZLER	1916	249
EDWARD E. BARRETT	1916	118
SOUTHERN STATES	1916	1482
NEVADA	1916	306
RAYMOND	1916	318
BOB	1916	190

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
BERTHA L	1916	141
FORTUNA	1916	564
NETTIE	1916	1188
GUYTON NO. 1	1916	193
GUYTON NO.1	1916	670
PILOT BOY	1916	301
MAY	1916	1057
LITTLE CHARLIE	1916	940
TEXAS GIRL	1916	1539
NICARAGUA	1916	308
HEREWARD	1917	207
BRAZOS	1917	66
MARIA LOUISA	1917	
ROBERT A. SNYDER	1917	353
IRMA BENTLEY	1917	
OTIS	1917	29;
DELAWARE SUN	1917	.
WILLIAM L. DOUGLAS	1917	400
PATTON	1917	353
BEN HUR	1917	136
CHARLES K. SCHULL	1917	313
BERTHA	1917	43
GUYTON NO.9	1918	673
LAKE CITY	1918	164
F.A. KILBURN	1918	135
UNKNOWN	1918	524
ROBERT	1918	381
MYLU	1918	293
PRIDE	1918	1301
ANNIE AND JENNIE	1918	74
BRILLIANT	1918	212
EMILIA GLORIA	1918	147
BESSIE WHITING	1918	42
F. 12	1918	120
F.12	1918	524
EUNICE	1918	515
ELIZABETH	1916	482
LOUIS H	1919	268
HUGH DE PAYANS	1919	
SANTA CHRISTINA	1919	407
WHITE SQUADRON	1919	1645
COPPERFIELD	1919	
CLEO	1919	343
MAGNOLIA	1919	1003
CITY OF PHILADELPHIA	1919	
UNKNOW	1919	35
CITY OF SARASOTA	1919	89
JOHN FRANCIS	1919	234
WASP	1919	564
CITY OF BILOXI	1919	
THOMAS L. WAND	1919	380
ALICE B. PHILLIPS	1919	
BESSIE	1919	148
GYPSY	1919	675
I.X.L.	1919	726
LOU ELLA	1919	965
VOLUNTEER	1919	1622
MILDRED COLLINS	1919	1072
TRAMP	1919	1576
RING DOVE	1919	1352
WILLIAM H. DAVENPORT	1920	
ALBERT W. ROBINSON	1920	
PRISCILLA L. RAY	1920	340
'Seaplane barge'	1s20	445
GRIFFIN	1920	148
FRED W. AYER	1920	

TABLE H-1 (CONTINUE).

SHIP NAME	YEAR	REF. NO.
T H WAND	1920	317
CATANIA	1920	61
NORTHWESTERN	1920	286
BOLIKOW	1920	35
RONA	1920	1370
JOHN M. EMERY	1920	196
JOHN. M. EMERY	1920	811
BADDACOCK	1920	35
UTINA	1920	
PLANTER	1921	639
UNKNOWN	1921	459
PAULINE G	1921	1258
BAGDAD	1921	47
BOBBI E	1921	191
LEWIS H. GOWARD	1921	258
PILOT	1921	1279
BON TEMPS	1921	197
THOMAS B. GARLAND	1921	446
BIG BAZOO	1921	165
FRANCIS	1921	573
AGNES BELLE	1921	24
LILLIE B.	1921	927
MASSACHUSETTS	1921	204
FLORENCE HARVEY	1921	.
SEABREEZE	1921	388
RICKETTS, V.C.	1921	
ANNETTA	1921	73
CAMBRAI	1921	.
HERBERT MAY	1922	178
CALDWELL H. COLT	1922	234
IOA M. SILVA	1922	214
COLTHRAPS	1922	105
JOSEPHINE	1922	822
CARRIE S. ALLEN	1923	296
BRONX	1923	74
ALTAMAHA	1923	15
BRONX	1923	52
BLUEFIELDS	1923	64
STRANGER	1923	
ANNIE MURPHY	1923	12
FOUR M'S	1924	568
LILLA	1924	S24
ROBIN HOOD	1924	
AVIS	1924	3s
AVIO	1924	45
ALPENA	1924	14
CORNELIAS H. CALLAGHAN	1S24	110
VALDARNO	1924	
EOLA	1925	507
GWAHA	1925	162
GWALIA	1925	1 90
'schooner '	1S25	443
ROSA A	1925	1374
LUDLOW	1925	981
SHEREWOG	1S26	
NANCY HANKS	1926	1176
SERAFINA C.	1926	1451
THENDARA	1926	443
WM. G. VANCE	1926	1663
ISLAND BELLE	1926	224
LIBERTY	1926	916
ROBERT B. BURNEY	1926	1361
IDA	1826	729
HYPNOTIST	1926	723
LEROY	1926	256
ROBERT L. BEAN	1926	354

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
MATTIE B	1926	1052
EOLA	1926	508
LOUISIANA	1926	185
ROSE	1926	1376
ALBERT MEYER	1927	11
ARTEMIS	1927	
CYNTHIANA	1927	379
UNKNOWN	1927	522
ROSE MURPHY	1927	356
MOORE NO.3	1927	304
NIMROD	1927	1197
IJAVELIN	1927	228
STRANGER	1927	432
MAURICE R. THURLOW	1927	288
T.C.I.S.G. NO.1	1927	1529
ALTHEA	1927	50
COLONEL MOORE	1927	92
PORTSMOUTH	1927	304
UNKNOWN	1926	500
ARAGO	1928	30
MONROE COUNTY	1s20	303
CHASE	1928	317
JOHN HENRY SHERMAN	1928	236
L. FARIES	1928	875
JIM DANDY	1929	783
E.E. SIMPSON	1929	130
BILLY	1929	176
ROSEMARY	1930	388
W.J. COLLE	1930	559
AMOS WATCHILT	1930	21
UNKNOWN	1930	521
E.E. SIMPSON	1930	412
ZALOPHUS	1930	578
UNKNOWN	1930	3040
UNKNOWN	"1930	3041
UNKNOWN	1930	3049
SALVOR 11	1931	368
POLLY P.	1931	1292
HIAWATHA	1931	181
UNKNOWN	1932	527
NEPENTHE	1932	303
MORNING STAR	1932	1152
EULALIA	1032	514
EXTRA	1932	523
HANNAH MARIE	1932	680
ELLA P.	1932	488
JOE C.	1S32	793
FAREWELL	1933	533
UNKNOWN	1933	395
DEL MAR	1933	407
PIECES OF EIGHT	1934	1278
3-R	1934	2
MARIE J. THOMPSON	1934	3122
ERICKSON	1934	3121
H.T. DeBARDELEBEN	1934	159
UNKNOWN	1s34	314
TRIO	1935	1580
UNKNOWN	1935	3132
UNKNOWN	1935	4202
UNKNOWN	1935	760
H.P.	1935	678
UNKNOWN	1936	3126
DREDGE	1936	102
UNKNOWN	1936	127
UNKNOWN	1936	377
E.E. SIMPSON	1936	439

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
MAYFLOWER	1936	1060
SADELL	1937	1403
ECHO	1937	464
ALMA	1937	45
Ed. BULLOCK	1938	.
MANHARTON	1938	448
BERLEON	1939	139
VENETIA	1939	548
TARPON	1939	2656
GRADY S.	1939	636
SOUNDING LINE WRECK	1940	425
BELMONT	1940	.
LEWIS BROTHERS	1940	221
STURDY	1940	1509
AUDREY	1940	100
BOORICHABOO	1941	203
BEN	1941	134
E.E. SIMPSON	1941	105
MANHARTON	1941	242
GLORIA COLITAUS	1941	183
GLORIA COLITA	1941	
SEA WITCH	1941	1445
JAPONICA	1941	187
UNTATA	1942	544
HALSEY	1942	197
BENWOOD	1942	55
J.A. MOFFITT, JR.	1942	181
CHERIE	1942	320
SANTORE	1942	350
MANAGUA	1942	637
UNKNOWN	1942	518
NORMAN H. DAVIS	1942	329
MANZANILLO	1942	197
SANTIAGO OE CUBA	1942	298
STURTEVANT	1942	642
U- 157	1942	29
COOT	1942	48
BARBARA	1942	116
VAMAR	1942	2626
EMPIRE	1942	149
HALO	1942	679
OAXACA	1942	341
ILLINOIS	1942	177
CAPTIVA 11	1942	64
ATHENE	1943	41
GULFSTATE	1943	188
UNKNOWN	1943	4473
R-12 SS89	1943	281
MAJESTIC	1943	1004
UNKNOWN	1943	3120
DOLORES	1s43	73
GULFPORT	1943	O6
VIKING	1943	552
GALVESTON	1943	172
OCEANIC	1943	1215
PATTY	1943	1256
PATRICIA M	1943	1253
A.B.L._92	1s43	10
EMANUELA C.	1943	496
MARGATE	1943	416
TITAN	1943	
Sc 1063	1943	375
A B L 92	1943	406
GALVESTON USA	1943	434
VITRIC	1944	73
H.H. COnway	1944	55

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
MARIA	.1944	199
SPINDRIFT	1944	56
UNKNOWN	1944	447
SOUTHERN BREEZE	1944	360
KATHERINE II	1944	843
S-16	1945	33
MAGNOLIA	1945	449
RAINBOW	1945	1327
10WAN	1945	736
CAYMAN SALVAGEMASTER	11945	228
ORION	1945	
A.G.T. NO.34	1946	3
DIXIE BELL	1946	424
ANETA	1946	64
OLO RIVER	1947	346
LOICE L	1947	959
OKEECHOBEE	1947	345
PORTARITSA	1947	1296
QUARTER BOAT 357	1947	311
CLARIBEL	1947	84
HOBO	1947	713
PURETA	1948	1316
VAGABOND	1948	1597
BARBARA	1948	117
B.F. MOODY	1948	103
UNKNOWN	1948	640
NANDOMA	1948	311
W.F. FERGUSON	1948	1627
WILD DUCK	1948	399
GROVER CLEVELANO	1948	644
SAN SABA	1948	413
LT. W. ROBINSON III	1948	970
OSPREY	1949	1233
FALCON	1949	530
J.E. GRADY	1949	752
GALTEX	1949	594
GULL	1949	668
JOSEPHINE	1949	821
K-O	1949	837
I LDA	1949	176
WILD WINO	1950	1648
DEMOCRATIC	1950	415
LILLIAN	1950	S26
ALBERT ARTHUR	1950	34
JOETTA	1950	194
GRAZIA CERINO	1950	641
SADIE	1950	1404
OSCEOLA	1950	1232
BETTY	1951	153
JOAN C	1951	789
DESIRE	1951	120
DAYCO	1951	399
DORSYL	1951	445
LITTLE JOE	1951	952
D-6	1951	382
EL CAPITAN	1951	
TRAVELER	1951	1570
GIMICK	1951	617
MARETA	1952	1011
CAPT. FRANK	1952	254
MISS NANCY	1952	1126
FLYING DUTCHMAN	1952	560
MACKIE	1952	997
SA-LA	1952	394
SEACLDUD	1952	1448
CATHERINE	1952	302

SHIP NAME	YEAR	REF. ND.
SEA CLOUD	1952	413
UNKNOWN	1952	641
MISS BERT	1952	
MISS. BERT	1952	1142
ROANOKE	1952	322
ROXY	1952	1306
FERRYLAND	1953	
MISS PRISCILLA	1853	1129
UNKNOWN	1s53	419
WHITE STAR	1953	1646
JOHNNIE JUNIOR	1953	813
COLUMBIA	1953	96
PHYLLIS	1953	300
PENNANT	1953	1270
FOUR KIOS	1953	130
ELLIOTT	1954	491
YMS 319	1954	631
MARKIE SINGLETON	1954	1032
SPOT PACK	1954	
BIG APPLE	1954	60
SPOT JACK	1954	312
KON-TIKI	1954	244
SPORTSMAN	1954	1486
S.D.U.B. NO. 1	1954	401
UNKNOWN	1954	466
PROTECTOR	1954	376
M	1954	992
RIO HONDO	1s54	1353
SOUTH SEA	1954	311
JO-MARIE	1954	788
THREE FRIENDS	1954	452
CAPT. PHIL	1955	260
JEANNE	1955	776
CATERPILLAR	1955	57
COOKIE	1955	360
NO. B-29	1955	326
KIMTOO	1955	243
S. GONZALEZ	1955	1395
UNKNOWN	1955	456
PEARL HARBOR	1955	1260
DOLLEE	1955	427
JAMES CLOONEY	1955	185
SALTDOME NO. 1	1955	408
CORAL SANDS	1955	105
UNKNOWN	1955	472
D-B	1955	109
YUKPA	1955	1674
BLACK GOLD	1955	31
LUCKY LAOY	1955	877
JIFFIE	1955	782
EMPRESS	1955	145
MAYFLOWER	1955	1059
LUCILLE	1955	874
ALBATROSS	1955	5
SEA SPRAY	1956	1443
GOLDEN K	1956	630
RESTAURADOR	1S56	1346
THE BIRMINGHAM QUEEN	1956	1546
TEMPLE	1956	375
JOHN SCOTT	1956	807
CHARLIE MASON	1956	67
VALLEY PRINCE	1956	1600
TEXAS STAR	1956	451
TILEMAN	1956	454
MARTHA ANN	1956	1033
Miss COLUMBIA	1957	1094

SHIP NAME	YEAR	REF. NO.
SANTA BARBARA	1957	1422
ATMAR	1957	98
CACTUS	1957	232
PEACE 11	1957	1259
WAASY T. JR.	1957	1631
FILLETE	1957	1367
JUDY K.	1957	830
DAYCO	1957	118
LITTLE JIMMIE	1957	950
BUCCANEER	1957	218
TOMMY/GALE	1957	3589
JOE LECKICH, JR.	1957	794
FLAMINGO	1957	424
HICO	1957	171
ANN	1957	69
UNKNOWN	1957	472
WM. HAYES	1957	538
DR. BILLY	1957	448
WEST POINTER	1957	398
1.0. WAFER	1957	725
EBB TIOE	1957	462
DIXIE DANOY	1957	93
CAPTAIN GENE	1957	62
REVONOC	1958	1347
SUN QUEST	1958	1513
UNKNOWN	1958	3232
EVENING STAR	1958	522
EVENING STAR	1958	152
DANIA	1958	116
FLYING ACE	1958	559
VIRGINIA-MAY	1958	1618
ELIZABETH M.	1958	484
HORNET	1958	717
J. EDWIN TREAKLE	1958	748
D_3	1958	4 5 5
RESOLUTE	1958	390
JOHN ANO MARY	1958	228
WHITE SANO II	1958	1644
NARDY BOY	1958	331
I'M READY	1958	724
FAIR MOON	1958	154
FREDIA L.	1958	582
UNKNOWN	1958	666
FOLLY QUEEN	1958	563
CAPTAIN READY	1958	64
SHERRON	1959	1456
MR. HOPPY	1959	1162
VIRGINIA ANN	1s59	1615
PAMELA ANN	1959	1244
MISS FLETA	1959	1 100
LOUANNA	1959	267
OH-NO	1959	1220
PAUL TAYLOR	1959	1257
BRYN MAWR	1959	217
MARIETA K. II	1959	1023
JOAN OF ARC	1959	192
JOHN S.	1959	806
DIANA	1959	423
DENEBOLA	1959	116
MISS BEVERLY	1959	1089
FERDINAND MAGELLAN	1959	125
40_FATHOM NO. 30	1959	4
PRINCESS JULANNE	1959	308
ROSEINA II	1959	1380
CAPTAIN WALLING	1959	54
DMA	1959	1225

SHIP NAME	YEAR	REF. NO.
CAROLYN ANN	1959	292
LARK	1960	899
PEGGY 111	1960	1265
NEMO	1960	1186
BETTY EARL	1960	156
LEGION	1960	906
IMAGINATION	1960	732
CAPE LOOKOUT	1960	241
EMILY A.	1960	498
CAPTAIN RED	1960	274
VALINTINE	1960	1598
CRACKER'S BOYS	1960	374
SILVER KING	1960	1465
UNKNOWN	1960	3580
COLLE 7	1960	3630
UNKNOWN	1960	3634
UNKNOWN	1960	3520
MACARTHUR	1960	995
EVA LOUISE	1960	517
MARY ROSE	1960	1049
RO 5	1960	321
BELLE CLAIRE	1960	22
RIVERSIDE III	1960	1357
RIPTIDE	1960	1354
SOUTHERN BELLE	1960	1478
MISS BEHAVE	1960	1086
COASTAL II	1960	348
POLLY D	1960	382
MISS MILDRED	1960	1122
BAMA	1960	383
JOE M.	1960	193
DELL-D	1960	112
POCAHONTAS	1960	302
SAN JACINTO	1960	412
NOVIA	1960	1211
GULF TRADER	1960	151
FROG	1960	585
MARY E	1961	1040
GLADYS	1961	620
MAOAM QUEEN II	1961	273
JENKINS ROBERTS	1961	.
BUDDY LYNN	1961	77
SALTAIR	1961	1411
MARJIA B.	1961	1029
CAROLYN A	1961	3544
GOOD BROTHERS	1961	437
LADY PHYLLIS	1961	894
MISS LILLIAN	1961	1117
J.R. BOYD	1961	755
LEEVILLE	1961	219
CHARIE B.	1961	311
CAPTAIN PERRY	1961	52
DELTA	1961	411
BECKY-K	1961	128
MILRAY	1961	1076
ROY'S BOY	1961	1387
WM. CLARKE QUINN	1961	537
DORIS A	1961	439
RUTH KAY	1961	329
S.S.S. VIKING	1961	402
BARBARA 0.	1961	119
BILL HOLMES	1961	29
BILLY HOLMES	1961	178
JEZEBEL	1961	781
GOLDEN WEST	1961	145
FLEUR OE 11S	1961	547

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
BONNY	1961	201
ETHEL WALLING	1961	511
LUCY F.	1961	980
JOANIE B.	1962	791
YOGI	1962	1669
IRIS	1962	741
GRAND MAR	1962	640
MISS SARAH	1S62	301
DANNY BOY	1S62	394
BUNTING	1962	42
BESSIE	1962	146
MISS POWERAMA	1962	299
TORNADO	1962	453
BETTY J.	1962	158
LITTLE CHEABEAGUE	1962	941
B.J. WOODS	1962	104
BIDWELL AOAM	1962	163
CAPT. JIMMIE	1962	258
ANNIE BELL	1962	75
EMILY L.	1962	500
CHARLES SINGLETON	1962	314
FRANK B.	1962	575
BIG MAMA	1962	28
JACKO	1963	762
KATHRYN	1963	845
QUI VIVE	1963	1321
EDDIE BOY	1963	466
JAVA	1963	774
LUCKY	1963	975
CAROLINA EXPLORER	1963	57
RUDDIE O	1963	3437
SEA HORSE	1963	1439
FIL'E	1963	543
wAVE	1963	1638
YOUNG CHAMPION	1963	1670
LATHROP	1963	901
GINA & JOY	1963	618
KAREN SUE	1963	839
JOHNNIE GRASSO	1963	812
SEA HOUND	1963	1440
JOYCE HARDIMAN	1963	826
DANNY	1963	85
VALLEY RIO	1963	1601
BOUNTY	1963	54
ANNA M.	1963	25
YELLOW JACKET	1964	1668
BELLE TRIX	1964	645
REBECCA	1964	1338
BELLATRIX	1 S64	21
DAISY MAY	1964	390
SOUTHERN OAWN	1964	361
THE NORSEMAN	1964	1548
MARIPOSA	1964	1028
PEGGY SUE	1964	1266
BONNE FORTUNE	1964	36
HERO	1S64	704
L S U	1864	874
MISS PATRICIA	1964	264
TRIESTA	1964	4s8
UNKNDWN	1964	381
LADY JO	1964	086
HOOKER	1964	715
BERTHA V	1964	24
BERTHA V.	1964	145
CAPTAIN KENNY	1964	270
LITTLE BILL	1964	938

SHIP NAME	YEAR	REF. NO.
MISS GWEN	1964	1107
MISS JUDY	1964	1112
LACY PYBUS	1964	880
LYCO T	1964	234
LYCO I	1964	982
MARY CALL COLLINS	1964	1039
TEXAS NO.9	1964	1543
ROSALIE	1965	386
LUCKY STAR	1965	979
LITTLE BILL	1965	937
PAPA JON	1965	357
LESLIE ANN	1965	911
CINDY	1965	172
PEG	1965	1263
ROBERT P. DOHERTY	1965	385
UNKNOWN	1965	3617
HELEN S.	1965	167
MISS CAROL	1965	1091
CAPT. NOLAN	1965	259
L.T. 0210 JR.	1965	077
TRADE WINO	1965	1575
SAL & ZINA	1965	1408
LUCKY LADY	1965	976
STR OF THE SEA	1965	1505
SHAREE ANN	1965	1453
MISS ELLEN	1965	318
GEORGE JR.	1965	604
MIDCO	1965	316
KEY LARGO	1965	211
NOLAN R.	1965	285
LYCO IX	1965	285
HENRY BARRETT	1965	697
MISS MARGIE	1965	1120
GULF KING	1965	647
ST. JOSEPH	1965	1491
MR. ARJO	1965	270
DEBBY D	1966	403
GERTIE T	1966	612
CAPTAIN HARRY	1966	268
RANGER II	1966	1333
RANGER 111	1966	1334
BETTY RUTH	1966	160
BUHNDAY	1966	222
MISS STELLA	1966	1136
CANDICE	1966	
CELESTE JOAN	1966	64
TINSLEY	1966	1567
MALRII O	1966	1006
DOROTHY DIX	1966	443
CAPTAIN G	1966	266
UNKNOWN	1966	394
FULL MOON	1966	587
MR. MAGOD	1966	329
CAPTIN JOE	1966	280
LADY SUE	1966	895
LELA NATALIE	1966	907
PHEENIX SHAW	1966	1274
SUN RISE	1966	1514
PHEONIX SHAW	1966	368
PHOENIX SHAW	1966	297
MONALISA	1966	1148
TWO BROTHERS	1967	455
ALICE M	1967	36
CAPTAIN FRANK	1967	265
BAGS	1967	109
MARK E. SINGLETON	1967	281

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
IZAAK WALTON	1967	746
G. WHEEL	1967	589
UNKNOWN	1967	497
SILVER SANDS	1967	1468
MARION D.	1967	1025
QUEEN MARY II	1967	432
MARY B	1967	1038
MISS BETTY J.	1967	1088
C & C NO.3	1967	224
UKRAINE	1967	1591
MISS FULTON	1967	1102
LINDA LOU	1967	271
RANEY GRASSO	1967	1330
FOUR BROTHERS	1967	565
LITTLE GIANT	1967	274
BILLY p	1967	289
SEA BIRD	1967	420
MISS CONNIE	1967	258
CHAS. SCHREINER	1967	68
ARGO	1967	81
WHITE LAOY	1967	1642
DOUGHBOY	1967	447
ANGIE	1967	10
BEVERLY LIEAN	1967	27
BIG DADDY	1967	45
MISS LORRAINE	1968	1118
RODONSETTA	1968	1369
STRIPER	1968	1508
KINGFISH	1968	865
CRACKER JACK	1968	373
CORAL ISLE	1968	109
JEANNIE	1968	777
JOYCE M	1968	825
CAPT COX	1968	245
DAPHNE	1968	395
KHRISTY BEE	1968	858
DUBHE	1968	124
CONCH TOWN	1968	358
UNKNOWN	1968	2655
ST. VINCENT	1968	1495
HUSTLER	1968	721
MR. CLAY	1968	1159
UNKNOWN	1968	356
MISS CELESTE	1968	1093
PINTAIL	1968	1281
ARKANSAS	1968	85
CHIP	1968	326
HUNDRED PROOF	1968	720
EL GATO	1968	475
BONDAGE	1968	1S8
BILLIE BEA	1968	175
CHRIS F.	1968	328
TEMPEST	1968	1534
CASA MAR	1968	299
RIDALA	1968	1349
NANU	1969	1178
CAMILLE	1969	236
PIXIE	1S69	1283
GOOD LUCK	1969	633
SDC_2	1969	1433
NA ÑU	1969	222
GYPSY QUEEN	1969	677
SEA STAR	1969	304
MM_71	1969	1146
SILVER STAR	1969	1470
WILHELMENIA	1969	3631

SHIP NAME	YEAR	REF. NO.
TINA REE	1969	1566
THERESA F.	1969	74
LINDA ANITA	1969	930
TEE JAMES	1969	1533
L & L	1969	871
MISS RITA	1969	1130
DACRON	1969	385
WILMA JEAN	1969	1659
SNOW WHITE	1969	1474
JOHNNY K.	1969	234
VERNA SUE	1969	1606
CAPT. IJACK	1969	257
JOHN SEKUL	1969	809
UNKNOWN	1969	422
UNKNOWN	1969	316
CAPT. GALJOUR	1969	255
DUECES WILD	1969	454
GULF WIND	1969	662
SEA BREEZE	1969	1434
SOUTHERNER	1969	1483
BILLY P.	1969	48
KIT CAT	1969	866
MY DOLL	1969	1170
DELLA FRANCES	1969	410
MASTER STEVE	1969	1051
OCEANIC	1969	1214
WILMA	1969	535
DANDON	1969	392
GULF KING I	1969	648
NARCO	1969	1179
MISS ROSELLA	1969	1131
CEE DOT	1969	307
TRIENIN IV	1970	1579
CORAL SANDS	1970	367
SEA KING	1970	1441
GOODLUCK	1970	3104
MARIE	1970	1021
REGINA	1970	1344
SASSY GAL	1970	1428
SHIRLEY M	1970	1461
RUBY K.	1970	1389
3C	1970	3
SHRIMP BDAT	1970	420
UNKNOWN	1970	3526
GULF VIEW	1970	661
KAY ANN	1970	8s0
GULF DRILLER	1970	646
CORAL KEYS	1970	365
BIG RED	1970	
SONNY BOY	1970	1475
GULF MASTER	1970	655
MELLOW JAX	1970	1064
MISS SALLY	1s70	1132
CAPT . EDDIE "	1970	252
UNKNOWN	1s70	471
UNKNOWN	1970	492
LYCO XI	1970	886
CORAL CLIPPER	1970	362
LONESOME SAFARI	1970	961
ROBERT E	1970	1362
LOU JEAN	1970	966
FRANK J. MALCHAR	1970	576
JEANNIE B	1970	778
'STRANGER	1970	1506
LITTLE ANGLER	1970	.
BOB Y	1971	194

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. No.
KING CONCH	1971	863
SPRINGTIME	1971	1489
LORRAINE	1971	S64
JAMES MUNROE	1971	768
LILL CRUSO	1971	923
CAPT. FELIX	1971	253
MR. LEE	1971	1164
MISTER BOB	1971	1144
UNKNOWN	1971	2503
CALUMET	1971	235
ATHENA 11	1971	33
MERMAID	1971	1065
MAVERICK	1971	1056
PRINCESS KE AH SOM PAH	1971	1306
MISS LEIGH	1971	1116
ANITA BRYANT	1971	22
EX FREO T BERRY	1972	95
TURNABOUT	1972	1585
CIN CAT	1972	330
STARR L	1972	1501
TUNA	1972	1584
WAHOO	1972	1632
UNKNOWN	1972	3532
ELLA	1972	485
FREJABAR IV	1972	583
THE SEARCHER	1972	1550
LOCO NO. 2	1972	95a
CYNTHIA MARIA	1S72	378
LINDA ANN	1972	933
TOLERS TIGER	1972	1569
JACOBINA S.	1972	763
LISA A.	1972	936
PODUNK QUEEN	1972	308
SO-K	1972	276
PRINCE	1972	1302
ROSS AND BESS	1972	1383
CAPT. ROGER	1972	261
DON PEDRO	1972	429
FAIRWIND	1972	134
UNKNOWN	1972	501
MISS SANDRA	1973	3101
DEBORAH ELLEN	1973	405
ATHENIAN	1973	93
FLYING EAGLE	1973	561
Yso_71	1973	1672
FLO JO III	1973	550
DC_715	1973	400
MISTY	1973	1145
TAURUS	1973	3735
EULA LAVANA 11	1973	513
CATHERE	1973	301
SOUTHERN BELL	1973	1477
MISSY LEE	1973	1143
WHIPPOORWILL	1s73	1639
SILVER MOON	1973	1467
DALLAS JEAN	1973	391
BLUEBONNET	1s73	188
FRANKIE & TERRY	1973	577
MISS BARBARA	1s73	1084
LIBERTY BELL	1973	918
ORIENTAL CLIPPER	1973	1229
MARY ANN	1974	1036
MISS FIVE ELEVEN	1974	1099
CAPTAIN BUCK	1974	264
FANCY LADY	1974	531
ANNA MARIE	1974	71

SHIP NAME	YEAR	REF. NO.
AMERICAN TEAM	1974	55
ASTEROPE	1974	91
BROWARD II	1974	215
UNKNOWN	1974	205
UNKNOWN	1974	4201
SAN PABLO	1974	446
KING ANO I	1974	862
SUE	1974	1510
SWALLOWS FLIGHT	1974	1526
UNKNOWN	1974	3599
IRONSIDE	1974	2870
MY BABY	1974	766
RIG_3	1974	1351
EVE	1974	520
LITTLE BUDDY	1974	939
ALLIANCE	1974	44
ODYSSEY	1974	1217
PATSY O.	1974	1255
ROUSTABOUT	1974	1384
JUBILEE	1974	829
ROSE MARIE	1974	1378
L AND M	1974	873
GRANADA	1975	639
NORTHWIND	1975	1208
CAPT. GIBERSON	1975	256
PONCE	1975	1294
BLUE MARLIN	1975	184
BETTY ANN	1975	155
BILL ELLISON	1975	173
UNKNOWN	1975	2736
YANKEE CLIPPER	1975	3171
MARY K.	1975	1048
WHITE MARLIN	1975	1643
PARTNER	1975	1251
‘aircraft’	1975	3577
MISS BELLE	1975	3538
STAR OF PEACE	1975	1498
BEV AOELE	1975	3565
LADY DAISY	1975	883
AGS342	1975	25
PAPABOT’TE	1975	1247
OWNERS PR1OE	1975	1238
LAOY NELL	1975	891
KING FISH	1975	864
SARAH M	1975	1427
BRG_135	1975	211
B.P. NO.1	1975	105
VIKING	1975	1610
RIG	1976	1350
THERESE MICHELLE	1976	
TIKI	1S76	1564
KRISTA RO	1976	870
DORI MALYN	1976	437
UNKNOWN	1976	203
UNKNOWN	1976	204
FRANCILLE	1976	3217
DAVY’S NAVY	1976	3231
MISS JUDY	1976	1111
UNKNOWN	1976	2739
BETTY J	1976	3536
PAL JOEY	1976	1240
UNKNOWN	1976	2629
PATSY	1976	1254
MR. GUY	1976	1161
CAPTAIN PIP	1976	272
LADY JEVON	1976	885

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. m.
UNKNOWN	1976	407
MOON SHADOW	1976	1150
FINA V	1976	2501
ABYSS	1976	13
KERRI	1976	854
SPECS	1977	1484
MAR MAC	1977	1010
ALBACORE	1977	32
QUEEN R V	1977	3203
GEMINI II	1977	598
MISS ANN 11	1977	1082
UNKNOWN	1977	192
PERSEVERANCE	1977	1271
MAGEWIND	1977	173
GAIL EMMA	1977	593
UNKNOWN	1977	3219
CINDY BRENT	1977	3234
ERMA J. II	1977	509
BIG BUDDY	1977	166
R.O.6	1977	1323
BOBBIE ELAINE	1977	192
CAPT. STEVEN	1977	262
ARKANSAS	1977	84
SUSIE O 11	1977	1524
YOUNG JIM	1977	1671
PARAGON	1977	1248
PIsCES	1978	1282
UNKNOWN	1978	2547
MISS HOPE	1978	1110
SUSAN H	1978	1522
LADY SUSAN	1978	3224
UNKNOWN	1978	3233
UNKNOWN	1978	3539
UNKNOWN	1978	3632
DRUMMER	1978	3438
ALMA B.	1978	46
UNKNOWN	1978	407
CABOOSE	1978	231
ST MICHAEL	1978	306
JOE M. JR.	1978	796
CAJUN BABY	1978	233
MARGARET D. WEBSTER	1978	1013
BEACH COMBER	1978	125
KERRY DANCER	1978	855
MISS OARLENE	1979	1097
CAYMAN SALVAGEMASTER	11979	2570
EMILY BRown	1s79	25S4
UNKNOWN	1979	3129
CBC-21	1979	3533
UNKNOWN	1979	3530
M.J.K.	1979	993
CARO	1979	288
CAPN RON DU II	1979	243
OSPREY II	1s79	1234
WILMA G.	1979	.
KELLI D.	1979	85 1
GULF KING_36	1979	652
CAPT ROLAND	1979	248
EAGLESCLIFE	1879	4183
GULF KING_58	1979	653
DENNIS PRIDE	1979	417
UNKNOWN	1980	3719
FLINTSTONE	1980	548
KARMA	1980	3220
UNKNOWN	1980	3227
CAPT BEN MICHELL	1980	244

TABLE H-1 (CONTINUED).

SHIP NAME	YEAR	REF. NO.
BIG SKIPPER	1980	172
ANITA	1980	67
UNKNOWN	1980	3529
SEA PEARL	1980	1442
A.G. FISHER	1980	11
ALONA GIRL	1980	48
EMA	1980	495
OLE NO.5	1980	1222
UNKNOWN	1981	2575
UNKNOWN	1981	2577
SANDY P	1S81	3229
LITTLE TOTS	1981	3226
DONT CHA KNOW	1981	2920
UNKNOWN	1981	2921
UNKNOWN	1981	3616
DONNA MARIE	1981	425
UNKNOWN	1982	2574
UNKNOWN	1982	2573
DRIFTER	1982	2467
SEAWEEO V	1982	777
MISS TAMMY	1982	3218
SHORTY'S BOY	1982	3212
UNKNOWN	1982	3128
WANDA FOUR	1982	2628
DECCO 11	1982	69
UNKNOWN	1983	1324
UNKNOWN	1983	3531
LITTLETUB	1983	3602
UNKNOWN	1983	3328
UNKNOWN	1984	2922
RESTLESS	1984	655
LAOY LYNN	1984	2475
PAN DALLAS	1984	3329
DAVY'S NAVY	1984	3228
UNKNOWN	1984	2896
BUNGE 401	1984	3524
CAPT. GUEL	1984	3330
UNKNOWN	1984	3326
MARGIE B	1984	4186
REX	1985	285
USS EAGLE BOAT	1987	442
TARPON	1987	411
ANDREW JACKSON	1987	26

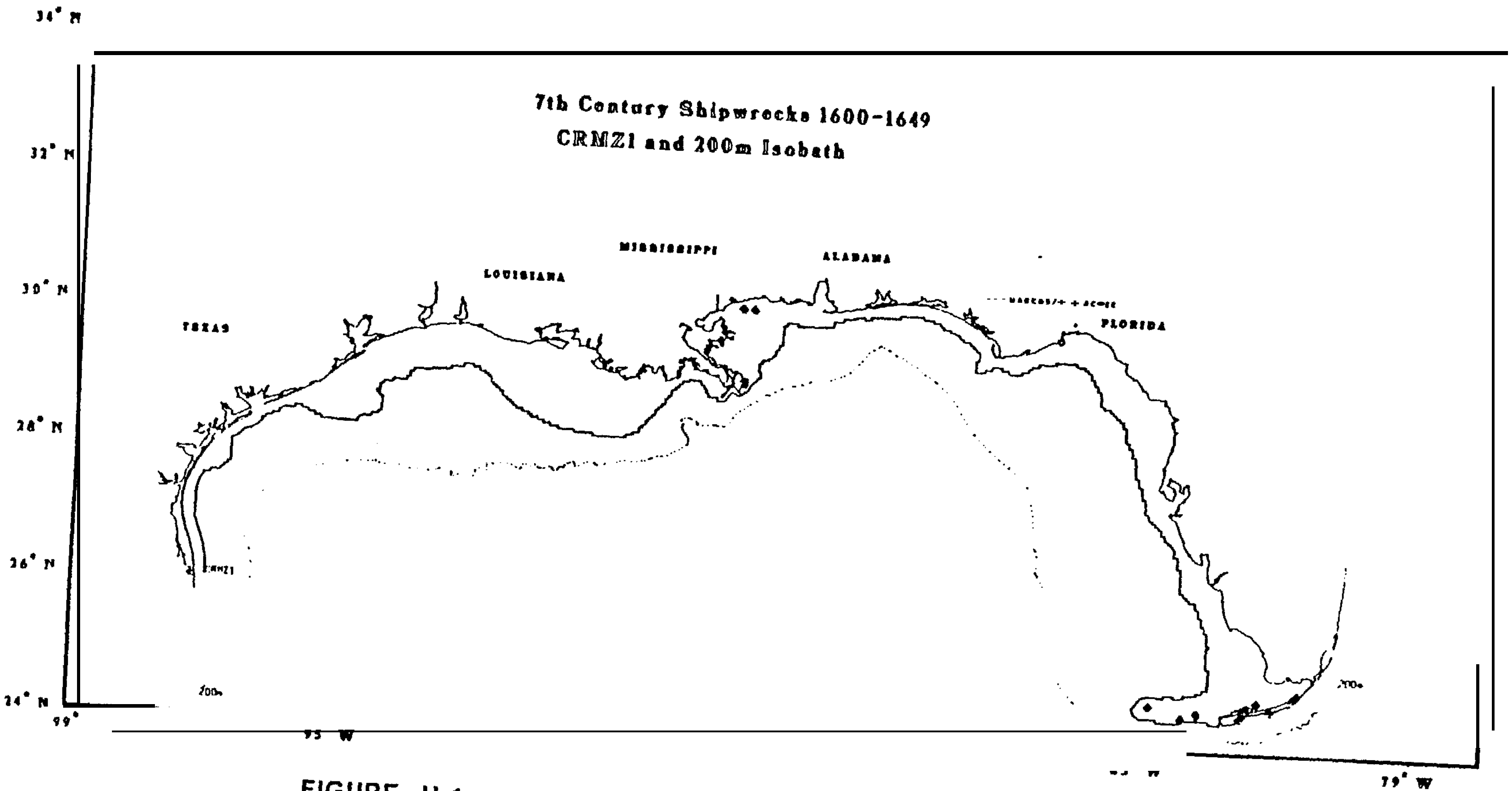

FIGURE H-1. 17th Century Shipwrecks 1600-1649 CRMZ1 and 200m Isobath.

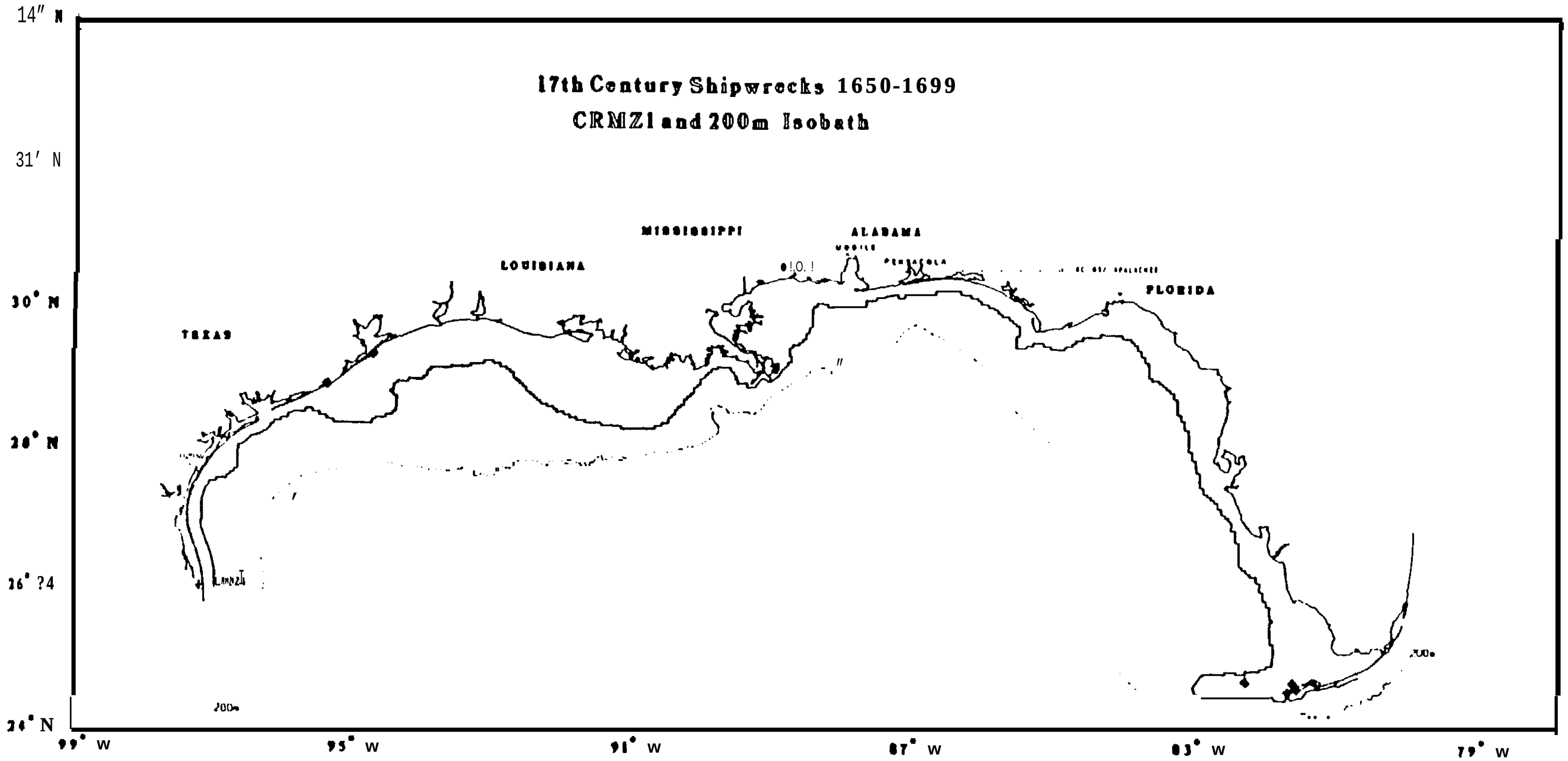

FIGURE H-2. 17th Century Shipwrecks 1650-1699 CRMZ1 and 200m Isobath.

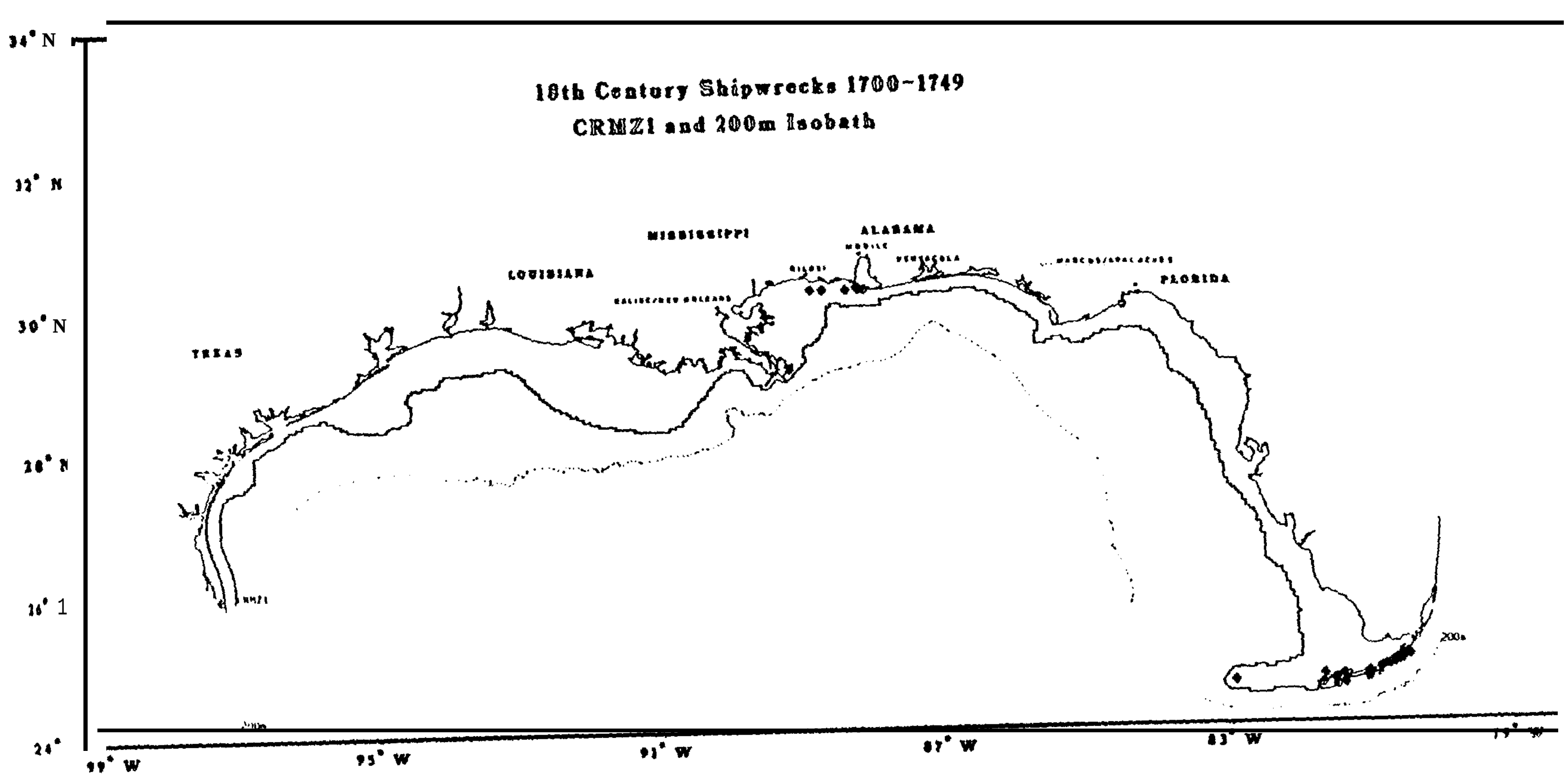

FIGURE H-3. 18th Century Shipwrecks 1700-1749 CRMZ1 and 200m Isobath.

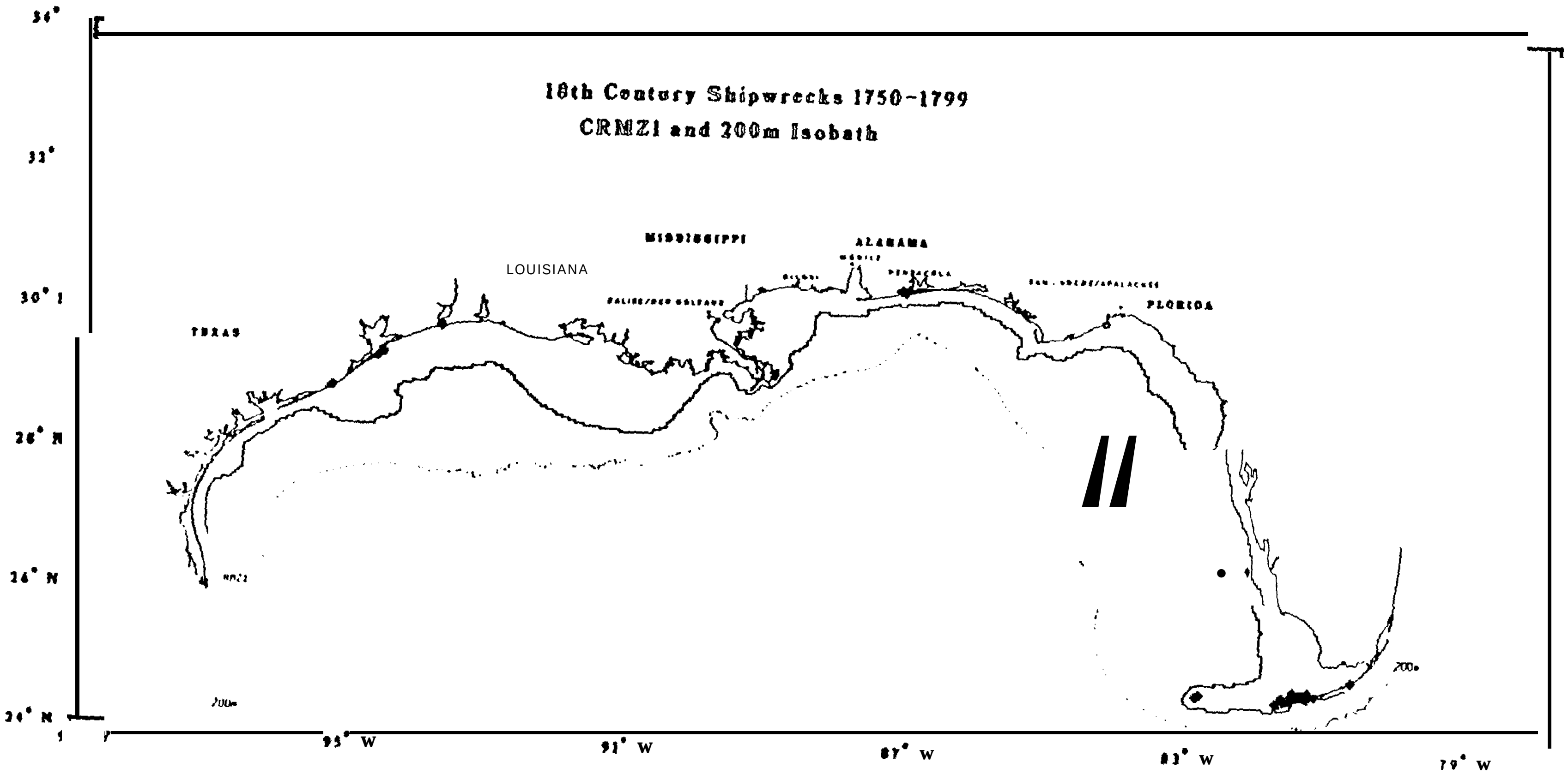

FIGURE H-4. 18th Century Shipwrecks 1750-1799 CRMZ1 and 200m Isobath.

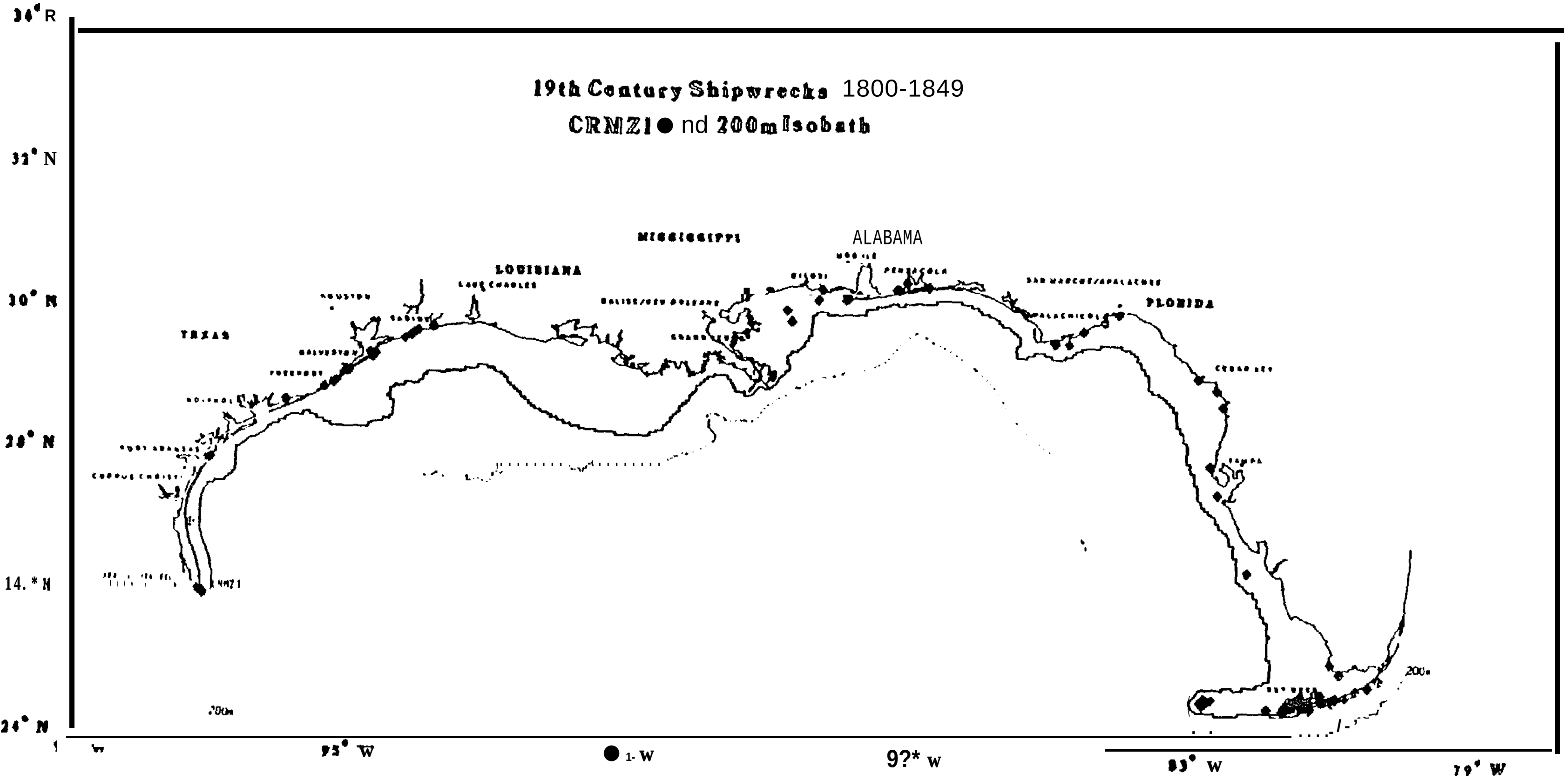

FIGURE H-5. 19th Century Shipwrecks 1800-1849 CRMZ1 and 200m Isobath.

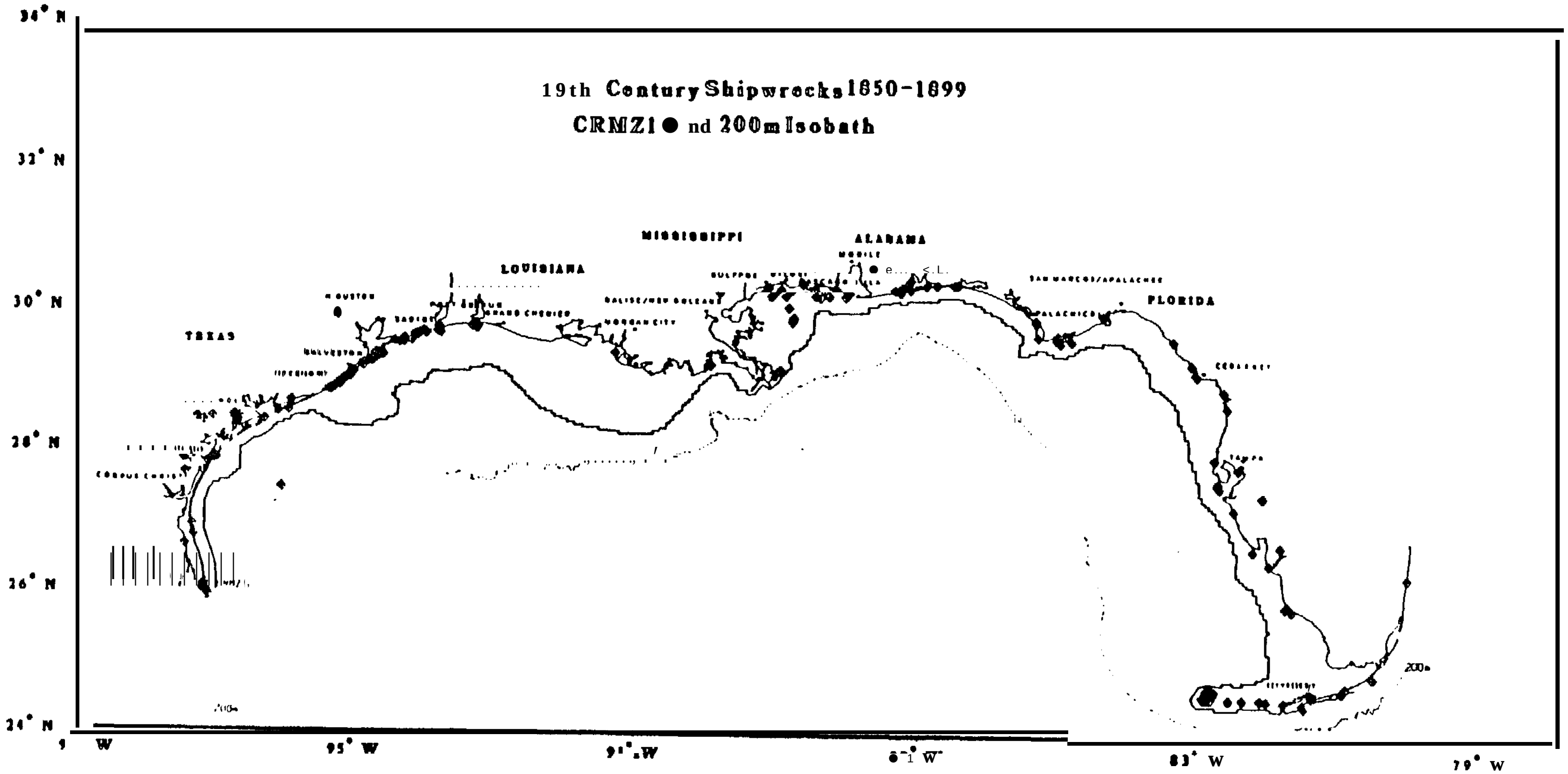

FIGURE H-6. 19th Century Shipwrecks 1850-1899 CRMZ1 and 200m Isobath.

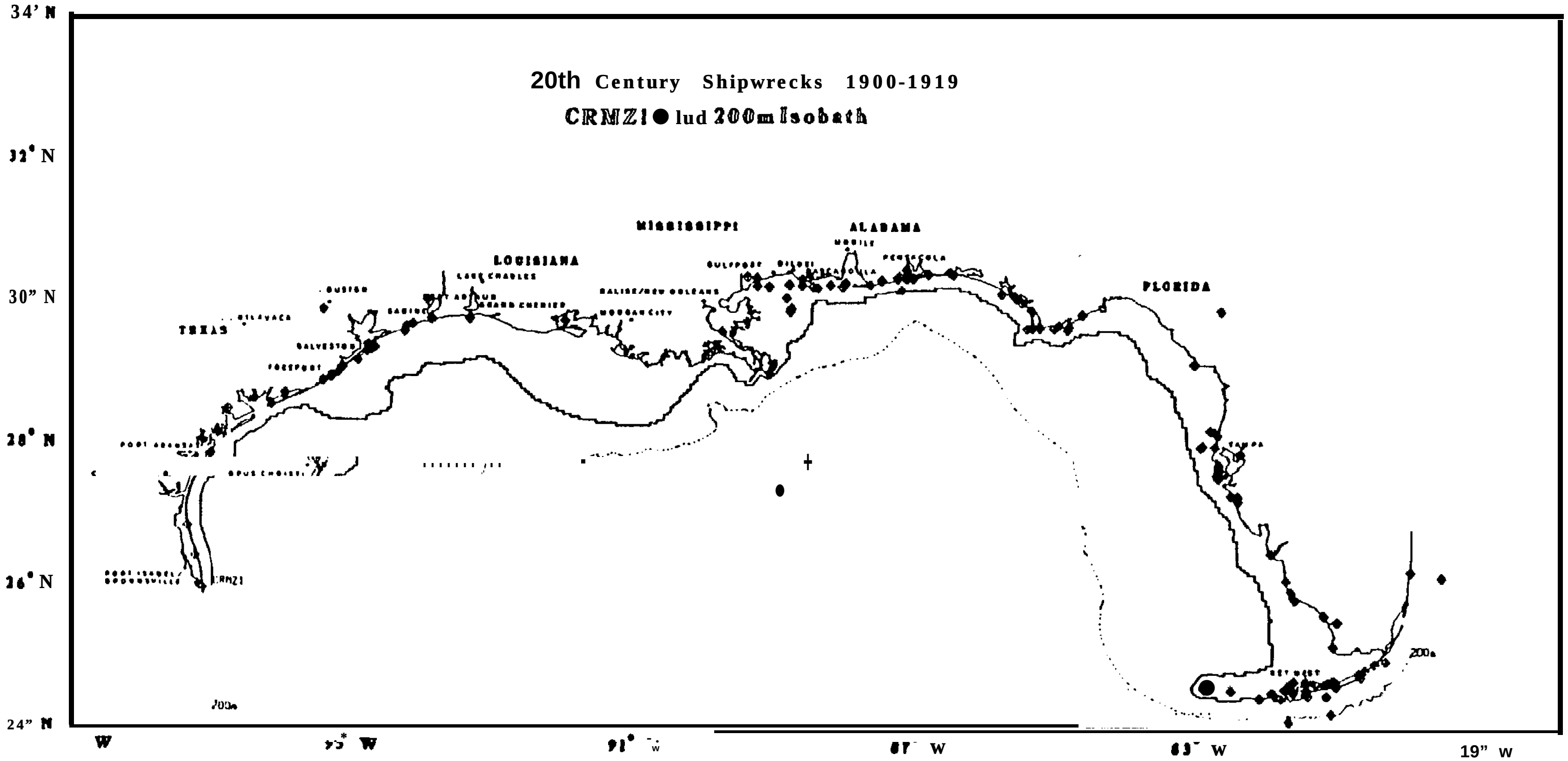

FIGURE H-7. 20th Century Shipwrecks 1900-1919 CRMZ1 and 200m Isobath.

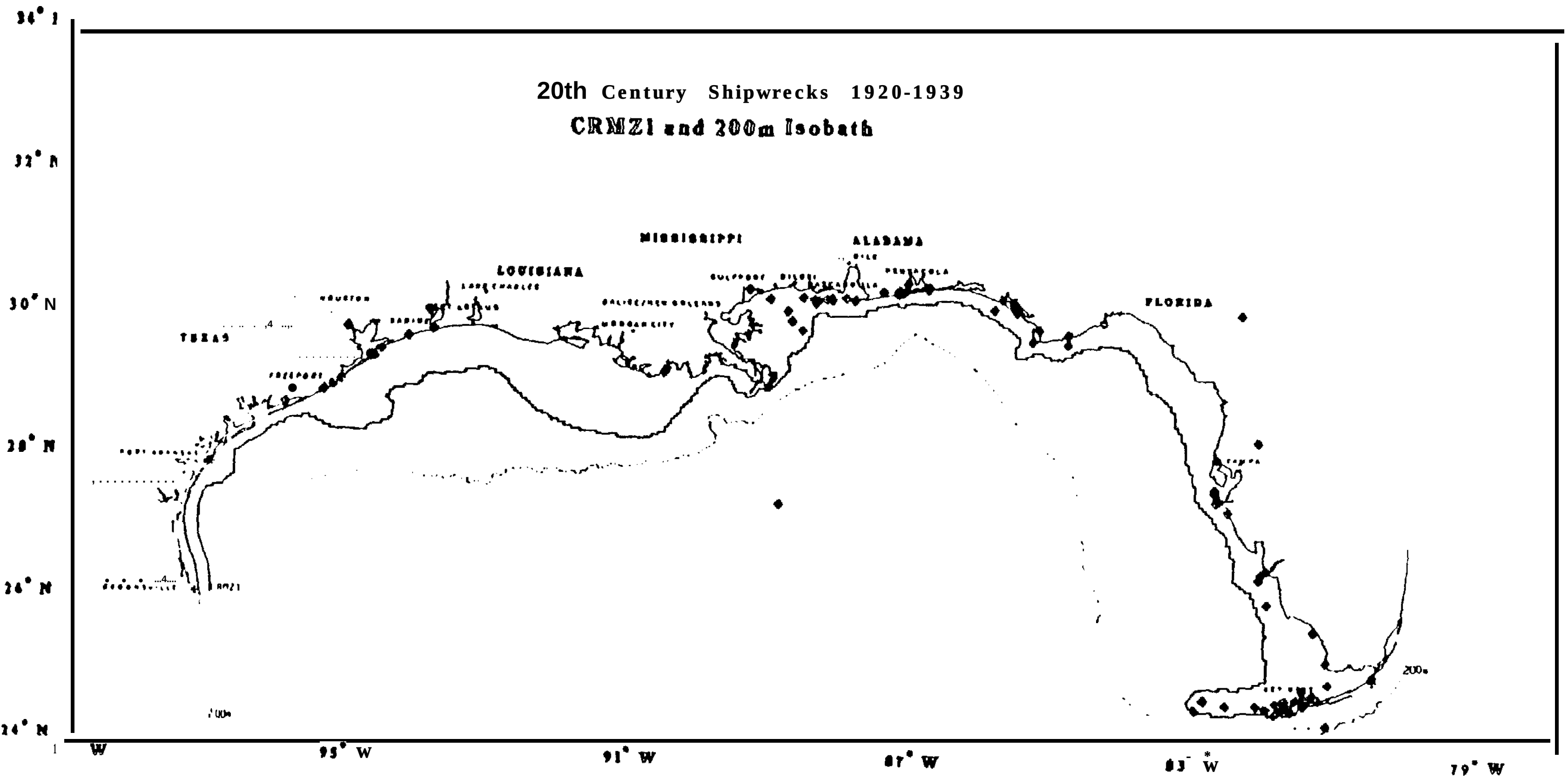

FIGURE H-8. 20th Century Shipwrecks 1920-1939 CRMZ1 and 200m Isobath.

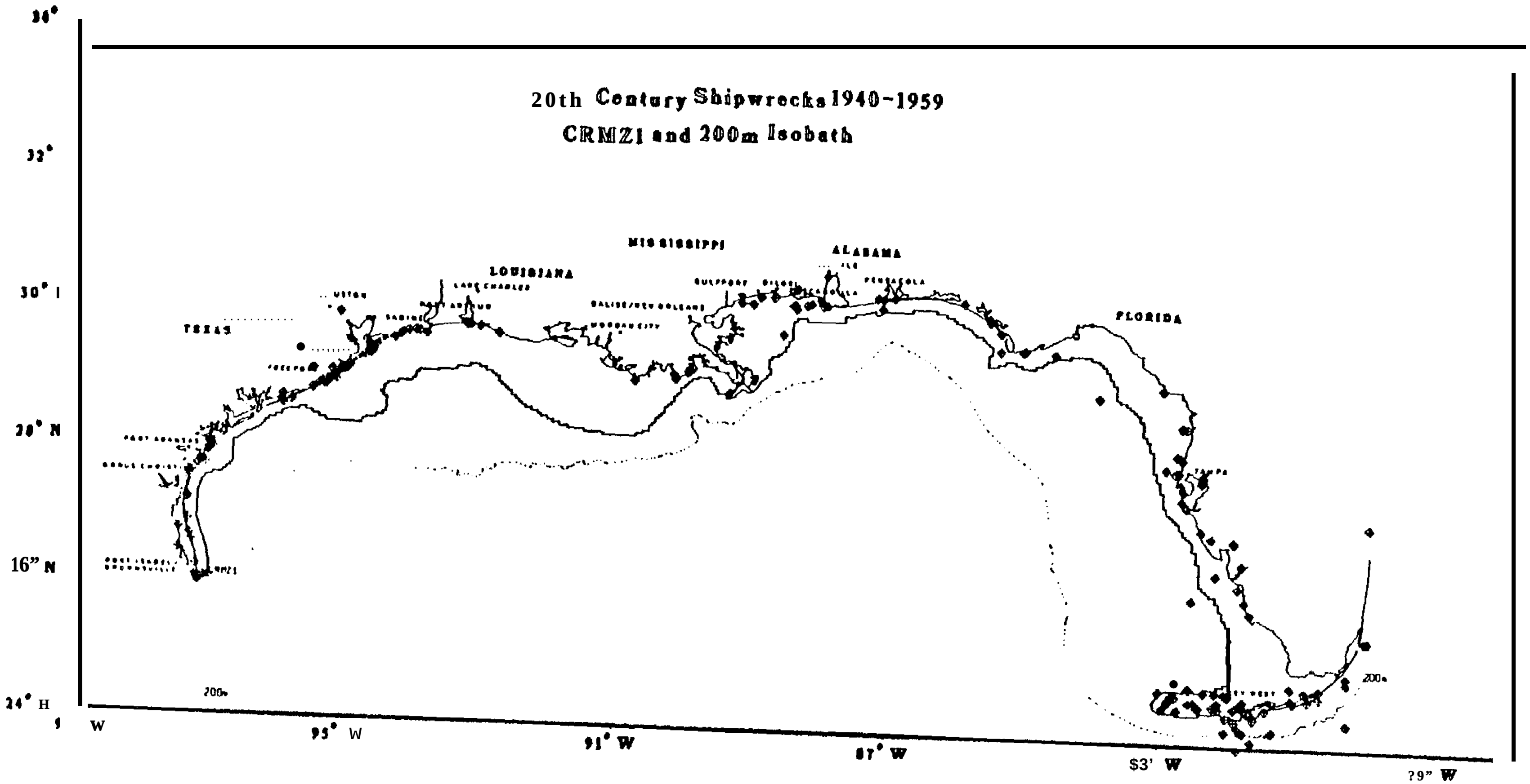

FIGURE H-9. 20th Century Shipwrecks 1940-1959 CRMZ1 and 200m Isobath.

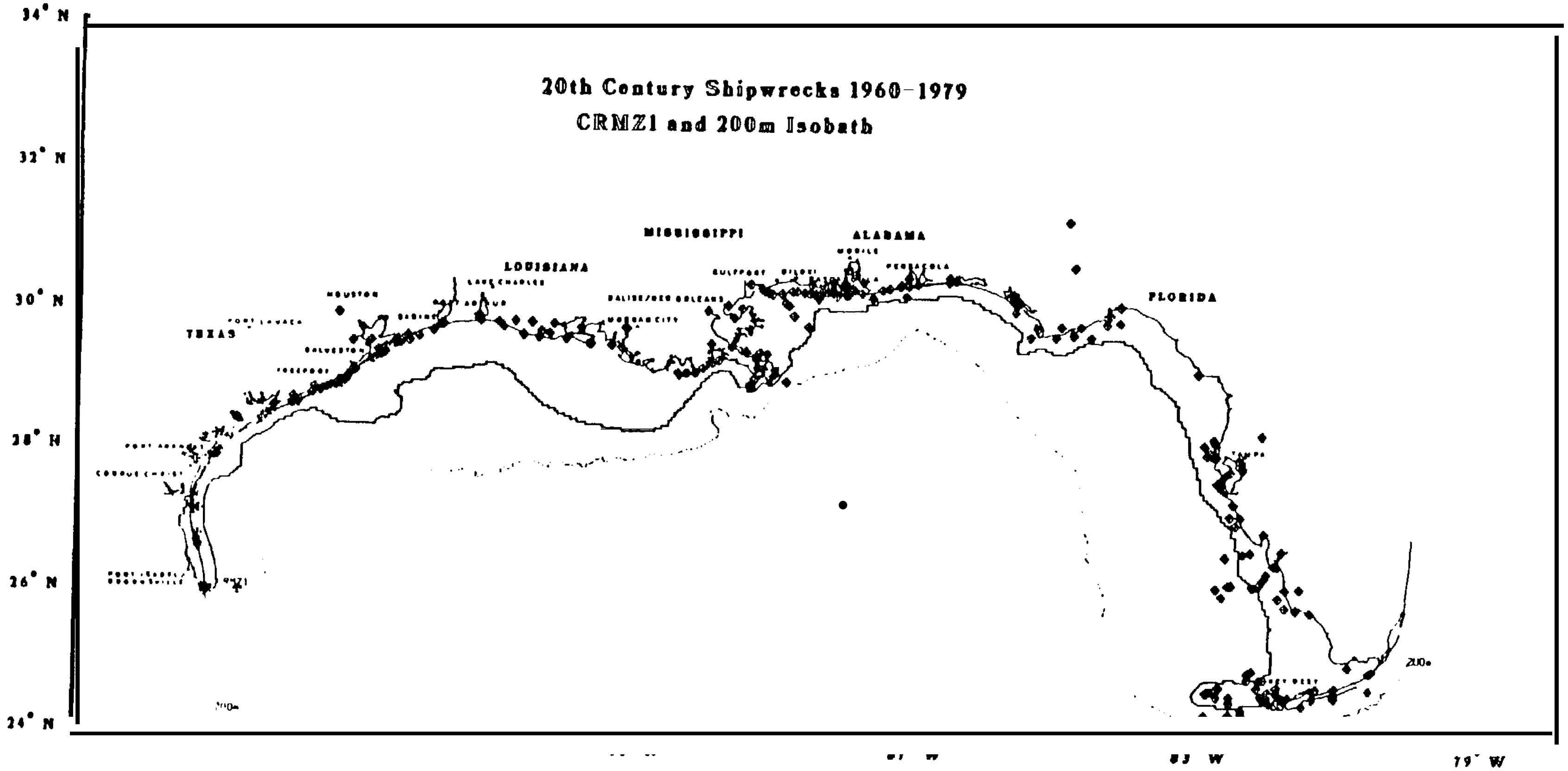

FIGURE H-10. 20th Century Shipwrecks 1960-1979 CRMZ1 and 200m Isobath.

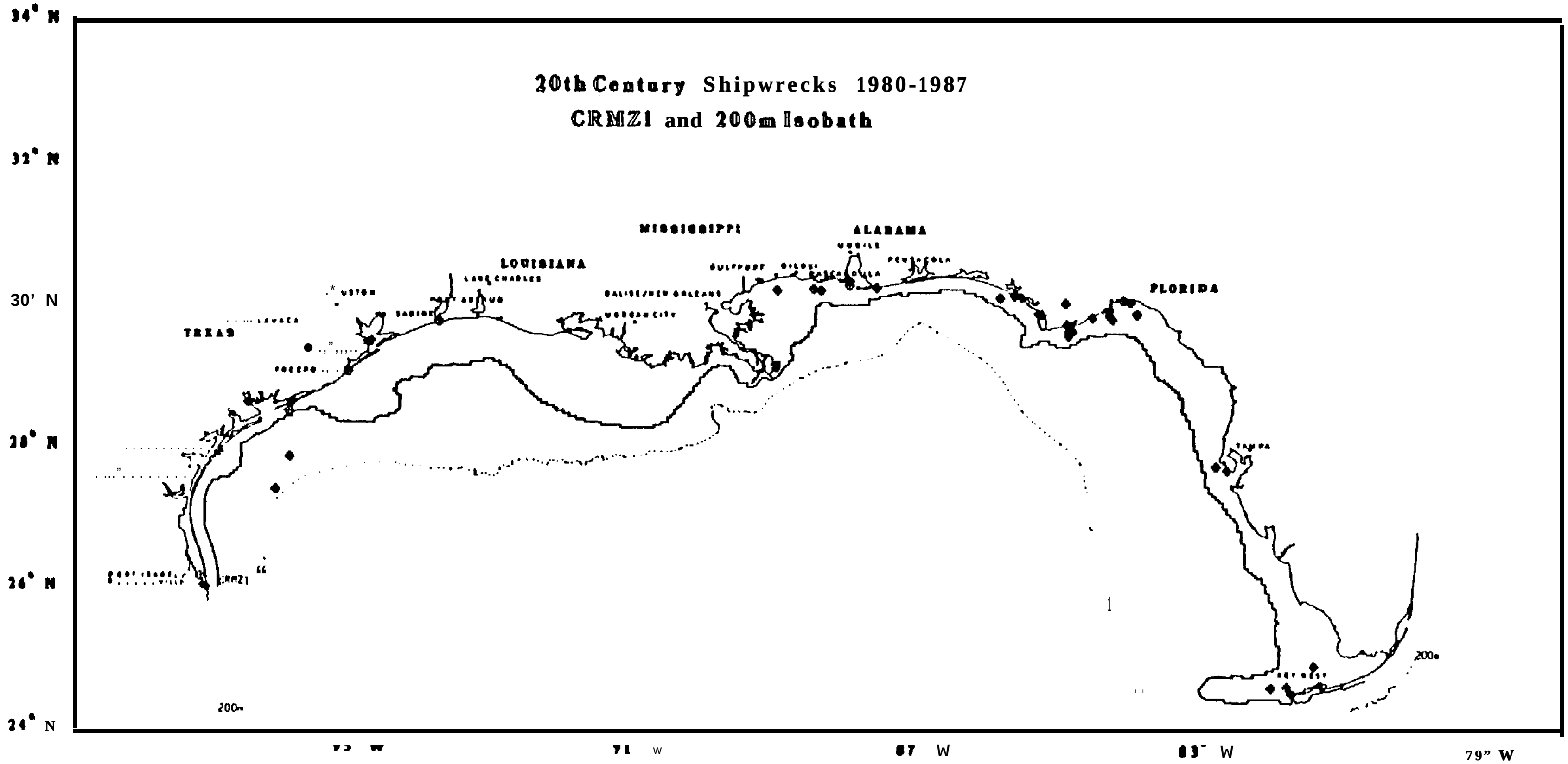

FIGURE H-1 1. 20th Century Shipwrecks 1980-1987 CRMZ1 and 200m Isobath.

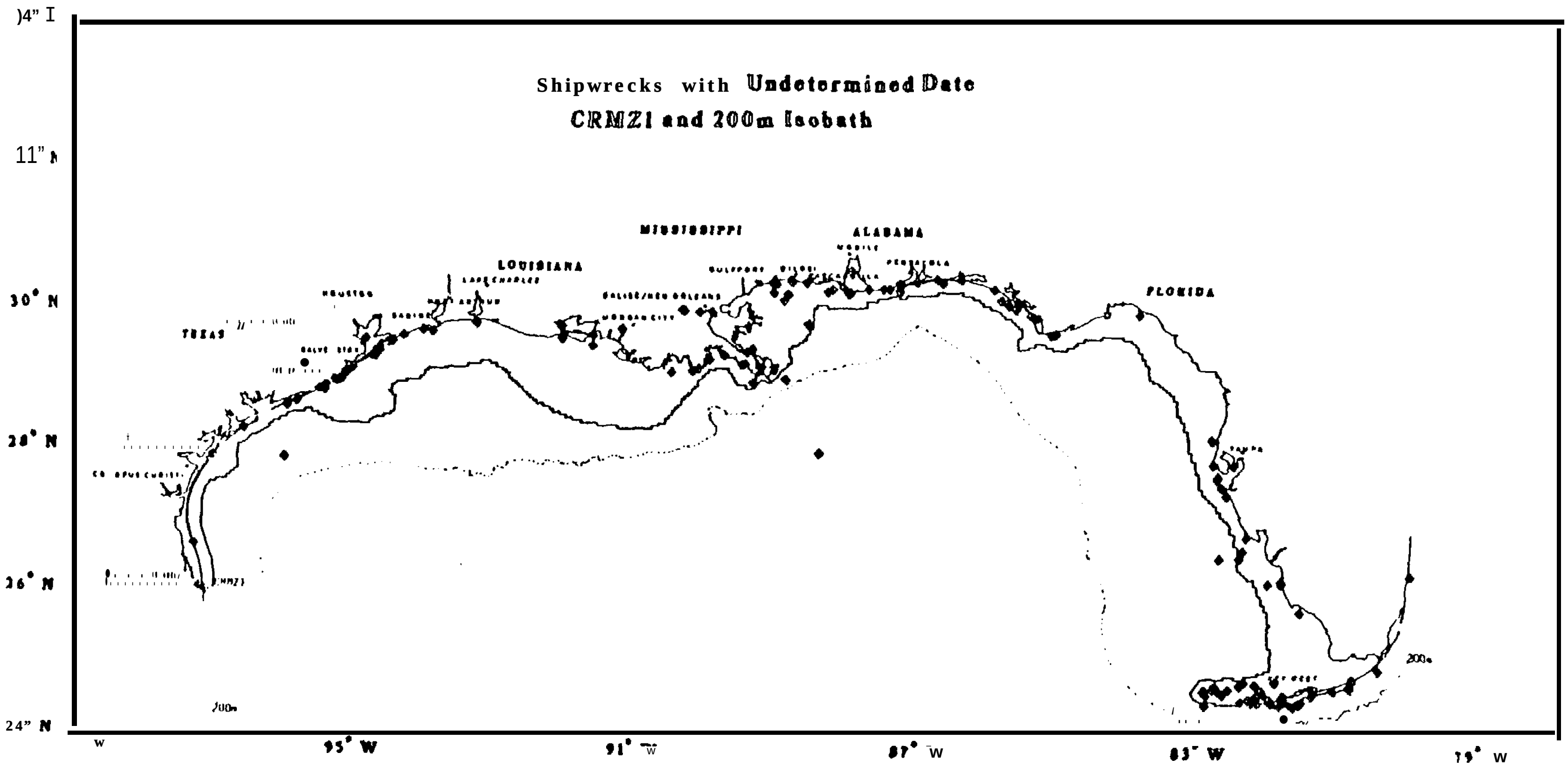

FIGURE H-12. Shipwrecks with Undetermined Date CRMZ1 and 200m Isobath.

APPENDIX I

Data for AMC Analyses, 0.5 and 1" Quadrats - $K \geq 10$; 50

Table 1-1.

Data for AMC Analysis; K≥10 (K = # Shipwrecks), 1° Quadrats'.

Latitude	Longitude	K
244961	804084	87
243431	813726	389
243657	824100	270
243323	831333	18
253444	813459	27
252673	823389	20
252607	833963	20
255159	963321	11
255683	970878	141
262701	815330	21
262074	822619	48
264210	833261	11
262552	861986	12
263700	881510	10
262578	964852	35
261777	970932	210
273462	824186	110
273424	831923	22
272694	872140	10
274349	953745	10
274266	964230	82
274130	970915	210
282211	824549	26
283145	833651	60
283181	841925	13
283666	883159	15
285034	892815	103
284443	903301	79
283786	912624	68
283930	922714	30
284079	932590	16
283550	943647	41
284709	952838	279
281910	962900	184
280824	970829	13
291656	832010	28
293293	843981	51
294039	852195	62
293386	862513	11
292615	872221	10
293715	884412	70
291824	893467	88
290855	902329	52
291598	913344	43
292409	923165	81
293895	933468	187
292280	943395	389

Table I-I
(continued).

Latitude	Longitude	K
290808	950917	73
300526	853946	40
302290	864191	26
301924	872055	119
301223	882544	163
301447	891443	48

Table 1-2,

Data for AMC Analysis; K≥50, 1° Quadrats.

Latitude	Longitude	K
248296	806833	87
245729	816243	388
246132	826858	270
259465	971491	142
263518	824407	50
262986	971582	210
275802	827004	110
277139	967077	82
276915	971552	210
285261	836124	60
288411	894712	103
287427	905522	79
286328	914388	68
287884	954762	279
283209	964869	184
295520	846652	51
296760	853683	62
296210	887372	70
293066	895799	88
291453	903908	52
294035	925290	81
296515	935798	187
293834	945690	389
291373	951563	73
303231	873455	119
302072	884263	163

Table 1-3.

Data for AMC Analysis; K≥10, 0.5° Quadrats.

Latitude	Longitude	K
243935	822550	15
246490	812702	96
246421	821610	52
247053	831919	12
259587	971499	139
263468	821226	21
261370	971473	153
267303	971818	56
271883	972726	22
277879	831247	11
277894	970857	170
281854	832583	10
283683	963459	95
281466	971096	12
287697	832266	12
288960	893421	68
287707	902467	33
288125	912220	27
288016	922992	14
288841	952978	185
285545	962543	18
291693	831261	19
292956	892680	30
290702	902526	30
292065	913269	15
292868	922131	26
293885	931847	22
292466	942615	30
290743	951176	64
297223	843445	10
296923	852542	47
296351	892447	12
297165	932699	58
296271	941678	83
303381	872707	96
302168	882319	100
302487	892025	45

Table 1-4. .

Data for AMC Analysis; K>50, 0.5° Quadrats.

Latitude	Longitude	K
246490	812702	96
246421	821610	52
259587	971499	139
261370	971473	153
276303	971818	56
277894	970857	170
283683	963459	95
288960	893421	68
288841	952978	185
290743	951176	64
297165	932699	58
296271	941678	83
303381	872707	96
302168	882319	100

APPENDIX J

Factor Analyses, Data Matrices and Factor Scores
- **Chronological Factors**
- **Areal Factors**

Chronological Factors

Table J-1.
Factor Analysis for Chronological Factors : $X_1 \ldots X7$.

Summary Information

Factor Procedure	Principal Component Analysis
Extraction Rule	Method Defau It
Transformation Method	Orthotran/Varimax
Number of Factors	3

Oblique Factor Scores: Columns 9-11

Table J-2.
Correlation matrix.

	Wrecks . . .	Wrecks . . .	Wrecks . . .	Wrecks . . .	Age Olde...	Ports, M...	Major S...
Wrecks 2...	1						
Wrecks 1...	.513	1					
Wrecks 1...	.547	.189	1				
Wrecks 1...	.528	.235	.982	1			
Age Olde...	.343	.253	-.096	-.142	1		
Ports, Ma...	.208	.296	-.163	-.156	.61	1	
Major St...	.382	-.001	.135	.077	.502	.046	1

Table J-3.
Partials in off-diagonals ● nd Squared Multiple R In diagonal.

	Wrecks . . .	Wrecks . . .	Wrecks . . .	Wrecks . . .	Age Olde...	Ports, M...	Major S...
Wrecks 2...	.604						
Wrecks 1...	.468	.415					
Wrecks 1...	.192	-.313	.972				
Wrecks 1...	-.069	.306	.976	.971			
Age Olde...	.077	.167	.205	-.247	.64		
PortS, Ma...	.124	.04	-.156	.128	.615	.494	
Major St...	.305	-.234	.058	-.063	.516	-.338	.453

Table J-4.
Measures of Variable Sampling Adequacy,
Total matrix sampling adequacy: .551

Wrecks 20th . .	.754
Wrecks 19th . .	.505
Wrecks 18th . .	.539
Wrecks 17-1 . .	.544
Age Oldest P...	.517
Ports, Major	.503
Major Storms	.441

Bartlett Test of Sphericity- DF: 27 Chi Square: 146.369 **P: .0001**

Table J-5.
Eigenvalues and Proportion of Original Variance.

	Magnitude	Variance Prop.
Value 1	2.676	.382
Value 2	2.067	.295
Value 3	1.1	.157
Value 4	.626	.089

Table **J-6.**
Eigenvectors.

	Vector 1	Vector 2	Vector 3	Vector 4
Wrecks 20th...	-.533	.102	-.009	.216
Wrecks 19th . . .	-.339	.186	-.561	.602
Wrecks 18th . . .	-.495	-.361	.051	-.294
Wrecks 17-...	-.489	-.376	-.021	-.272
Age Oldest P...	-.207	.582	.173	-.177
Ports, Major	-.115	.526	-.335	-.579
Major Storms	-.248	.26	.735	.252

Table J-7.
Unrotated Factor Matrix,

	Factor 1	Factor 2	Factor 3
Wrecks 20th...	.871	.146	-.01
Wrecks 19th . . .	.554	.267	-.588
Wrecks 18th . . .	.81	-.519	.054
Wrecks 17-...	.799	-.541	-.022
Age Oldest P...	.338	.837	.181
Ports, Major	.187	.756	-.351
Major Storms	.406	.374	.771

Table J-8.
Communality Summary.

	SMC	Final Estimate
Wrecks 20th . . .	.604	.78
Wrecks 19th . . .	.415	.725
Wrecks 18th . . .	,972	.928
Wrecks 17-...	.971	.932
Age Oldest P...	.64	.848
Ports, Major	.494	.73
Major Storms	.453	.899

Table **J-9.**
Orthogonal Transformation Solution-Varimax.

	Factor 1	Factor 2	Factor 3
Wrecks 20th . . .	.675	.448	.353
Wrecks 19th...	.352	.762	-.145
Wrecks 18th . . .	.96	-.071	.037
Wrecks 17-...	.964	-.043	-.038
Age Oldest P...	-.14	.595	.689
Ports, Major	-.218	.807	.177
Major Storms	.143	-.057	.936

Table J-10.
Oblique Solution Primary Pattern Matrix-Orthotran/Varimax.

	Factor 1	Factor 2	Factor 3
Wrecks 20th . . .	.726	.518	.418
Wrecks 19th . . .	.392	.786	-.085
Wrecks 18th . . .	.968	-.001	.09
Wrecks 17-...	.969	.023	.016
Age Oldest P...	-.071	.625	.717
Ports, Major	-.164	.808	.208
Major Storms	.19	-.001	.948

Table J-1 1.
Oblique Solution Reference Structure-Orthotran/Va rimax.

	Factor 1	Factor 2	Factor 3
Wrecks 20th...	.716	.511	.414
Wrecks 19th,..	.387	[.777	-.084
Wrecks 18th . . .	.955	-.001	.089
Wrecks 17-...	.956	.023	.016
Age Oldest P...	-.07	.617	.71
Ports, Major	-.162	.797	.206
Major Storms	.188	-.001	.938

Table J-12.
Primary Intercorrelations-Orthotran/Varimax.

	Factor 1	Factor 2	Factor 3
Factor 1	1		
Factor 2	-.119	1	
Factor 3	-.099	-.092	1

Table **J-13.**
Variable Complex ity-Orthot ran/Varlmax.

	Orthogonal	Oblique
Wrecks 20th...	2.315	2.474
Wrecks 19th,..	1.491	1.495
Wrecks 18th...	1.014	1.017
Wrecks 17-...	1.007	1.002
Age Oldest P...	2.05	1.985
Ports, Major	1.247	11.22
Major Storms	1.055	1.08
Average	1.454	1.468

Table J-14.
Proportionate Variance Contributions.

	Orthogonal	Oblique		
	Direct	Direct	Joint	Total
Factor 1	.431	.441	-.037	.403
Factor 2	.307	.324	-2.800E-4	.323
Factor 3	.262	.276	-.003	.273

Table J-1 5.
Factor Score Weights for Oblique Transformation Solution-Orthotra n/Va...

	Factor 1	Factor 2	Factor 3
Wrecks 20th . . .	.264	.207	.161
Wrecks 19th . . .	.138	.497	-.256
Wrecks 18th...	.387	-.056	.025
Wrecks 17-...	.389	-.025	-.035
Age Oldest P...	-.069	.24	.391
Ports, Major	-.096	.468	-.021
Major Storms	.047	-.213	.69

Table J-16.
Factor Score Weights **for Orthogonal Transformation Solution-Varimax.**

	Factor 1	Factor 2	Factor 3
Wrecks 20th...	.244	.182	.136
Wrecks 19th . . .	.123	.498	-.287
Wrecks 18th . . .	.387	-.083	.007
Wrecks 17-...	.391	-.05	-.054
Age Oldest P...	-.101	.226	.382
Ports, Major	-.12	.474	-.039
Major Storms	.024	-.246	.697

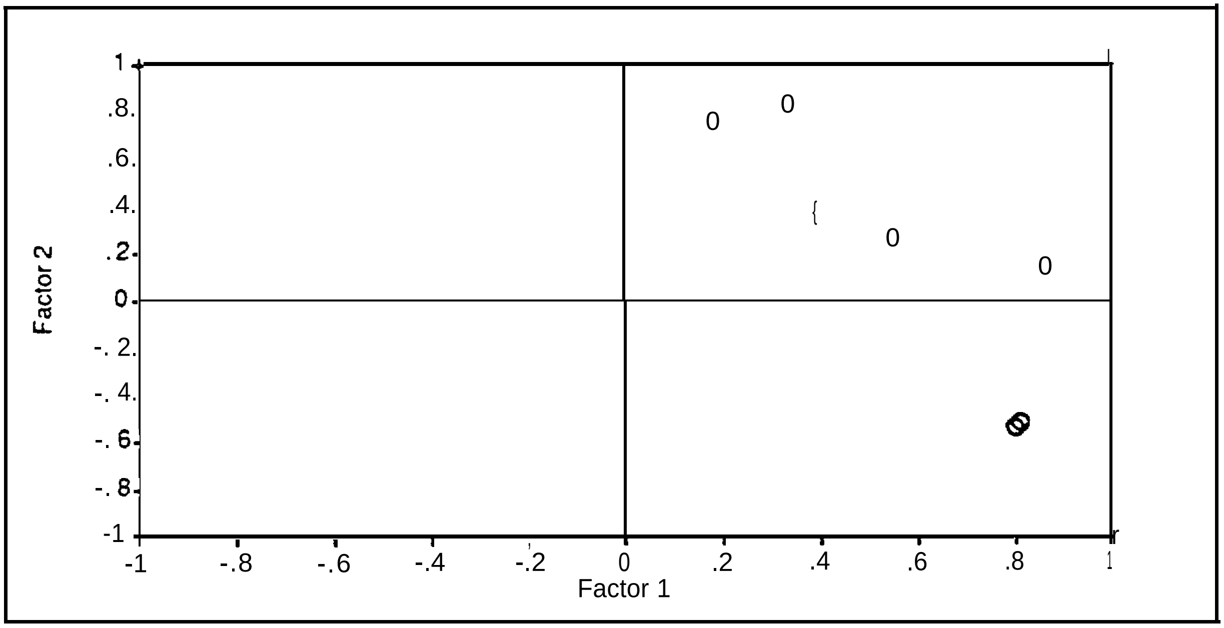

Figure J-1. **Unrotated** Orthogonal Plot: **Factor** 1 vs **Factor 2**.

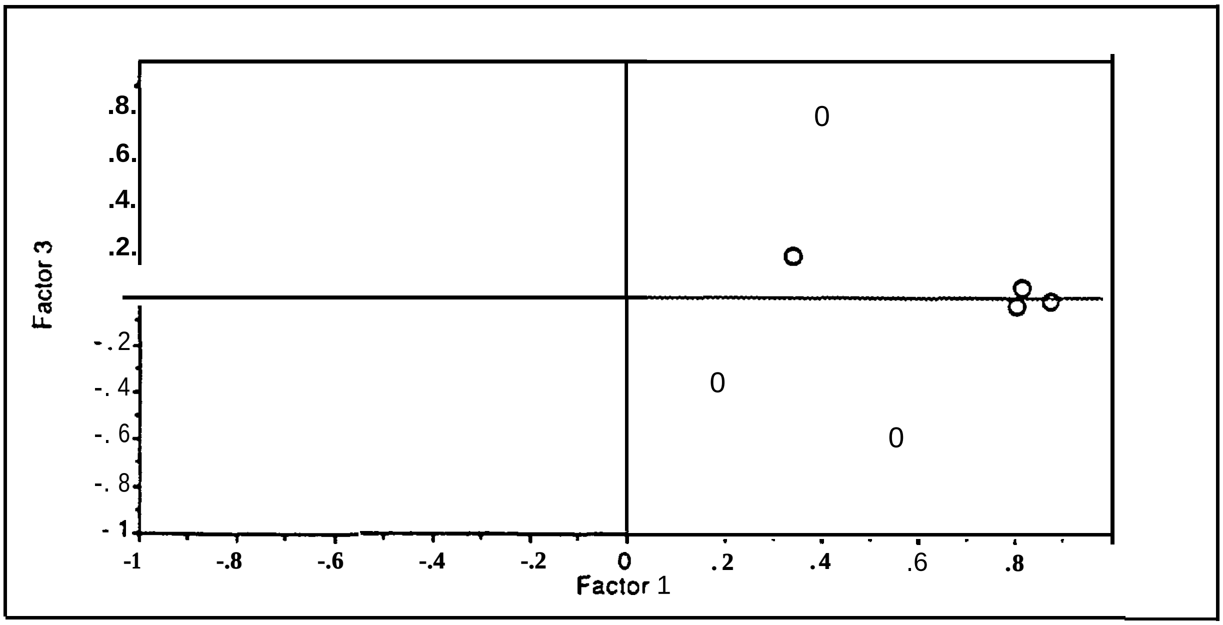

Figure J-2. Unrotated Orthogonal Plot: Factor 1 vs **Factor 3**.

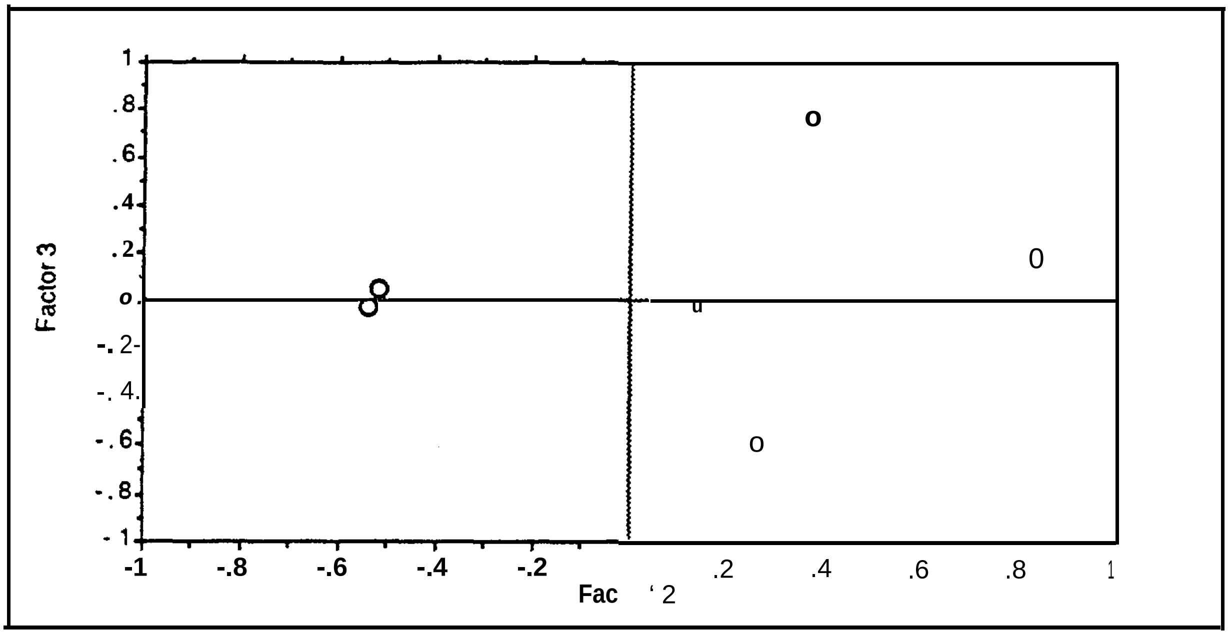

Figure J-3. Unrotated Orthogonal Plot: Factor 2 vs Factor 3.

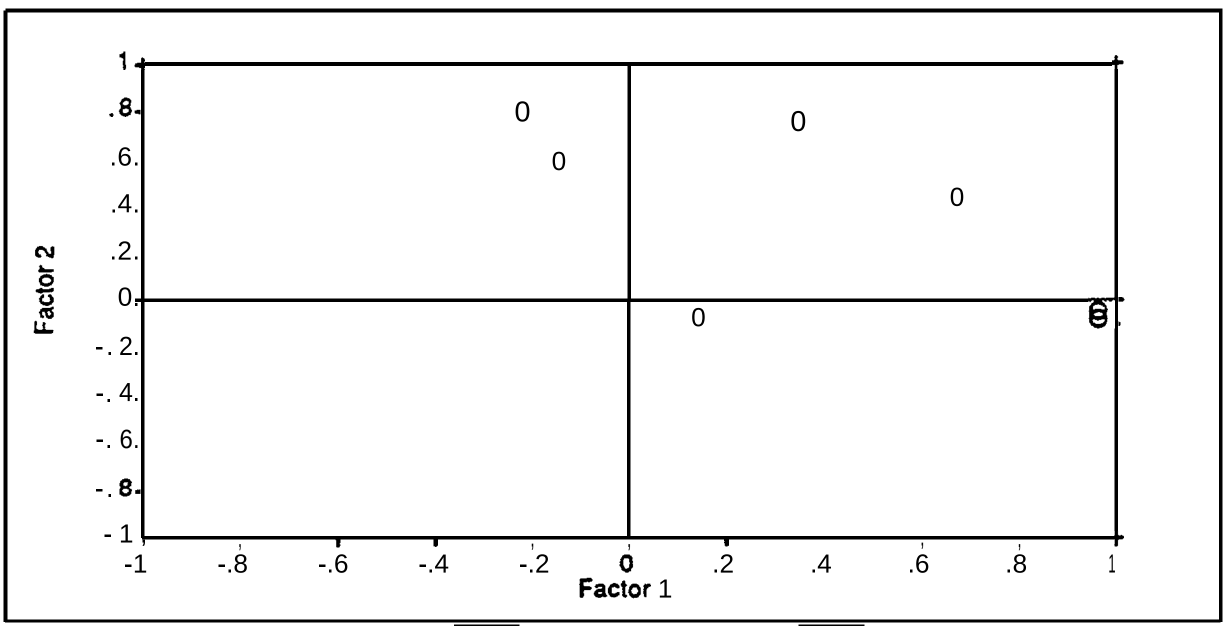

Figure J-4. Rotated Orthogonal Plot: Factor 1 vs Factor 2.

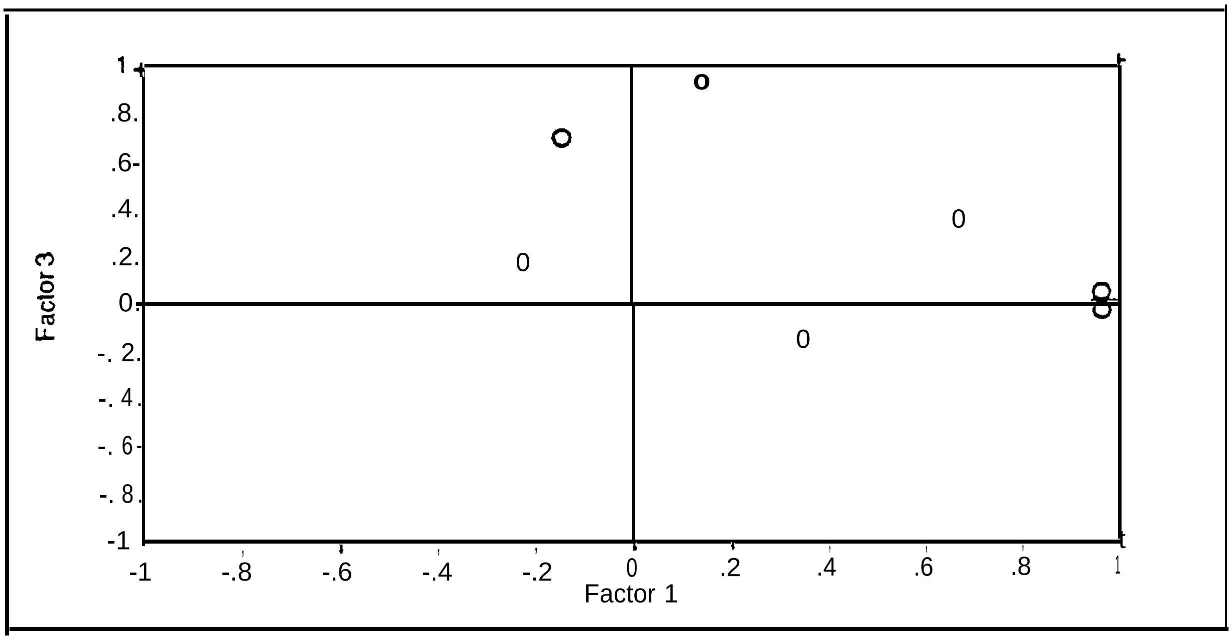

Figure J-5. Rotated Orthogonal Plot: Factor 1 vs Factor 3.

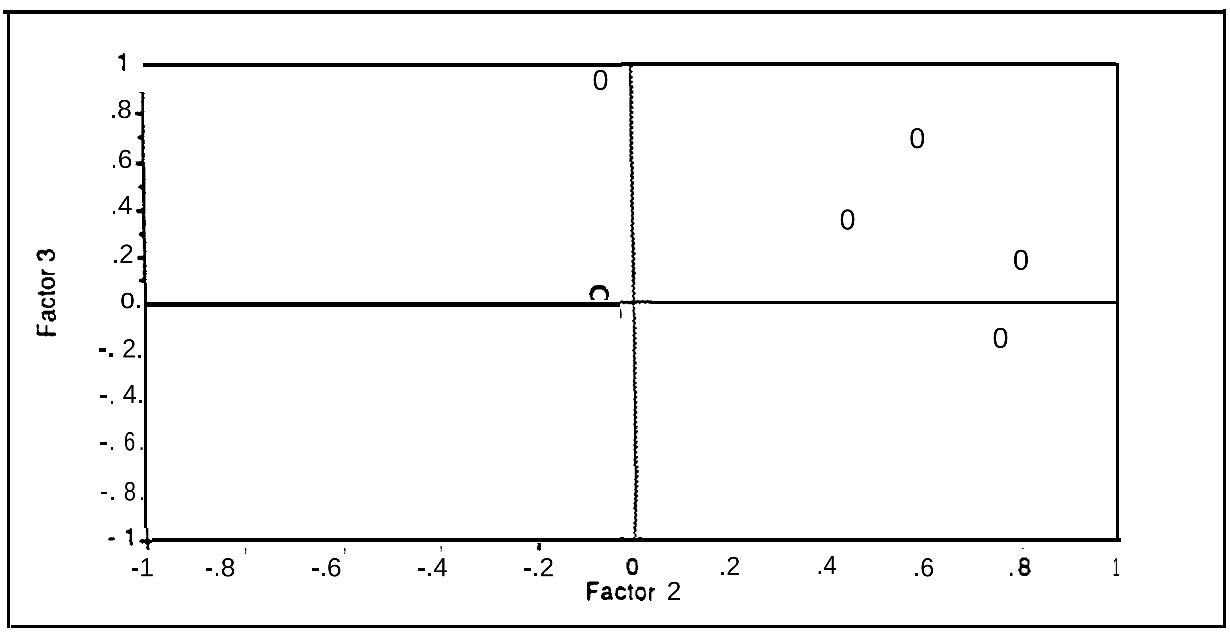

Figure J-6, Rotated Orthogonal Plot: Factor 2 vs Factor 3.

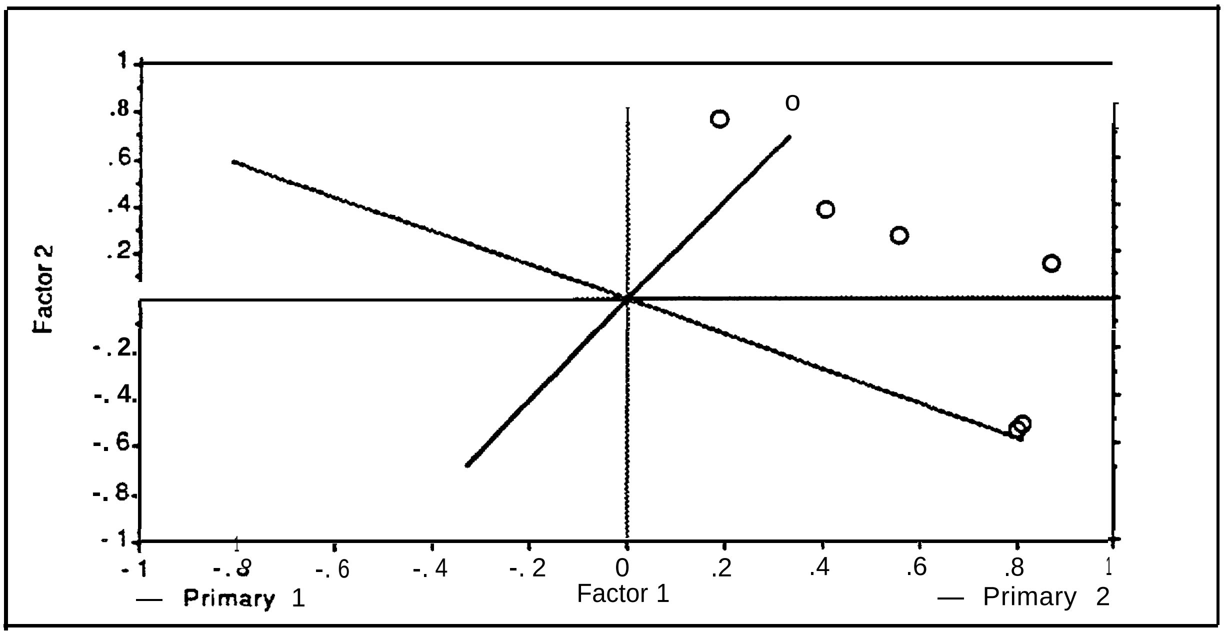

Figure J-7. Transformed Oblique Plot: Factor 1 vs Factor 2.

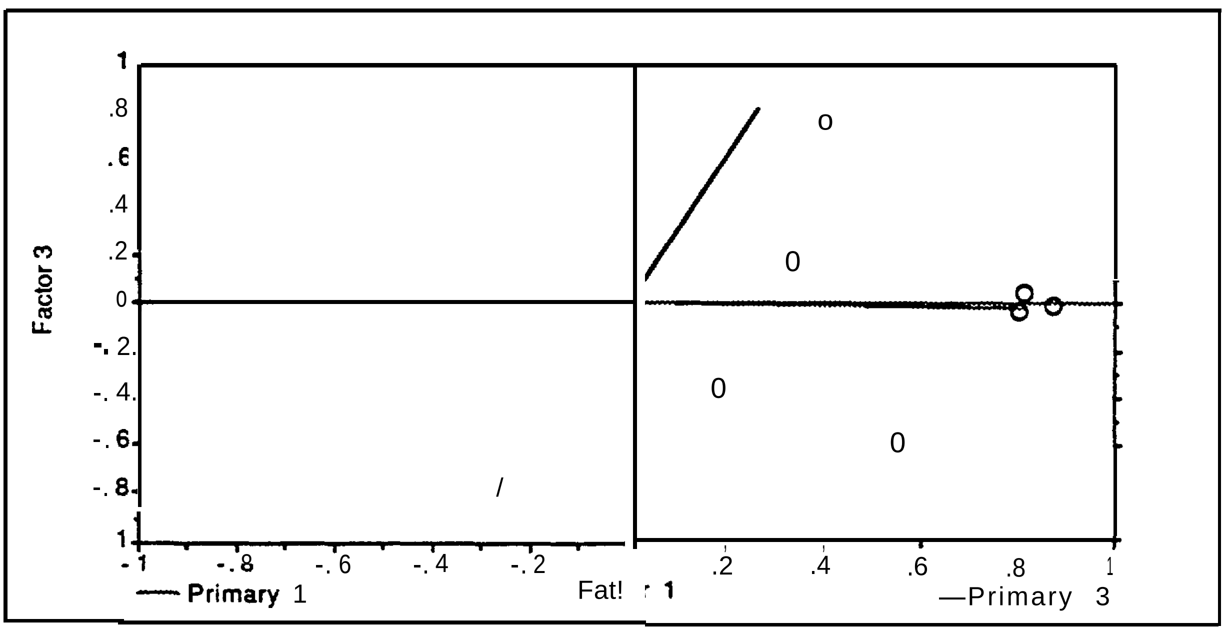

Figure J-8, Transformed Oblique Plot: Factor 1 vs Factor 3.

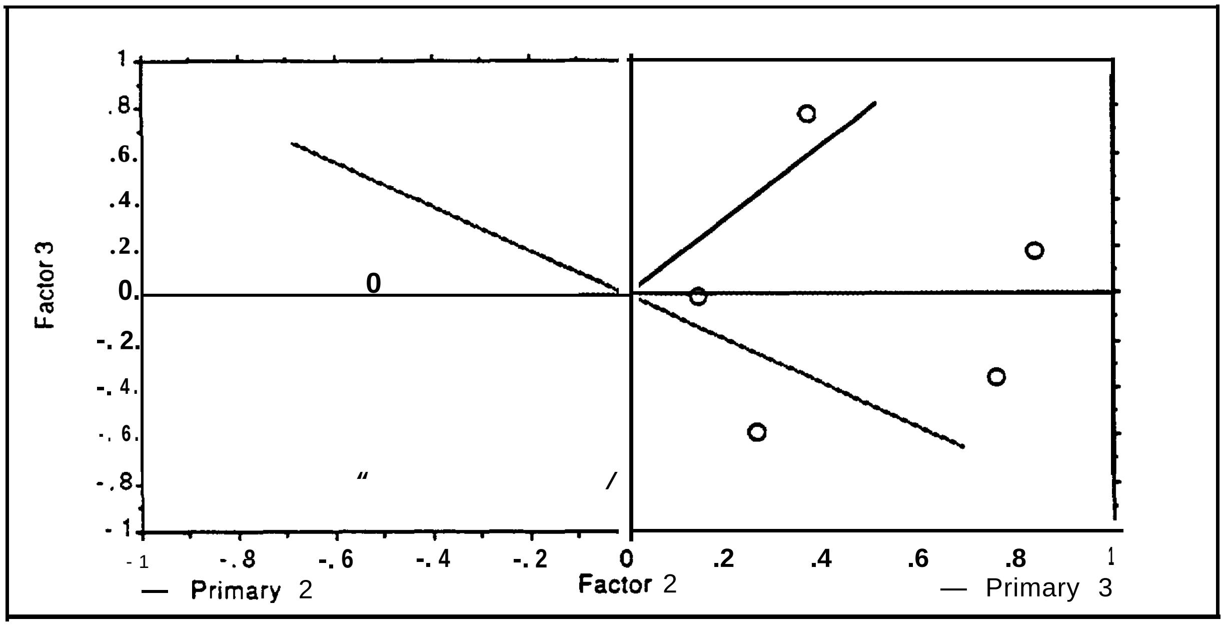

Figure J-9. Transformed Oblique Plot: Factor 2 vs Factor 3.

Table J-1 7.

Raw Data for Seven Chronological Variables for Twenty-Six **Gulf of Mexico** Areas, Brownsville to the Florida Keys.

	Wrecks 20th [.	Wrecks19th C.	Wrecks 18th C.	Wrecks 17-18th C.	Age Oldest Port	Ports,Major	Major Storms	Column 8
1	13	38	0	0	1 49	1	13	.
2	10	57	0	4	88	1	8	.
3	11	42	0	0	142	1	15	•
4	4?	69	0	2	1 44	1	10	.
5	6I	64	n	0	153	1	9	.
6	102	117	0	0	167	I	12	.
7	30	29	0	0	148	1	9	.
8	0	0	0	0	0	0	9	.
9	0	0	0	0	0	0	12	.
10	24	0	0	0	138	1	7	•
11	126	0	0	0	270	1	26	•
12	21	12	0	0	270	1	26	•
13	57	42	0	0	118	3	9	.
14	39	23	12	0	288	I	21	•
15	30	0	0	0	168	1	3	•
16	0	0	0	0	0	0	12	•
17	15	11	0	0	34	1	9	•
18	0	0	0	0	0	0	0	•
19	0	0	0	0	0	0	14	•
20	0	0	0	0	0	0	13	•
21	53	0	0	0	113	1	21	•
22	0	0	0	0	0	0	10	•
23	10	0	0	0	1 48	2	7	.
24	11	0	0	0	0	0	6	•
25	22	14	43	15	166	1	12	•
26	156	57	87	29	0	0	I 5	•

Area 1 = Brownsville; Area 26 = Dry Tortugas - Coastal Areas in 1 Degree increments.

Areal Factors

Table J-18.
Factor Analysis for Gulf ● rea factors1: $X_1 . . . X_6$

Summary Information

Factor Procedure	Principal Component Analysis
ExtractIon Rule	Method Default
Transformation Method	Orthotran/Varimax
Number of Factors	2

Orthogonal Factor Scores: Columns 8-9

Note: 5 cases deleted with missing values.

Table J-19.
Correlation matrix.

	Hurricane...	Ports	Routes	Hazards	Energy	Wrecks
Hurricanes	1					
Ports	.498	1				
Routes	-.505	-.496	1			
Hazards	-.299	-.329	.856	1		
Energy	.64	.171	-.643	-.478	1	
Wrecks	-.072	.567	-.215	-4.9 E-20	[-.25	1

Table J-20.
Partials In off-diagonals ● nd Squared Multiple R in diagonal.

	Hurricane...	Ports	Routes	Hazards	Energy	Wrecks
Hurricanes	.655					
Ports	.595	.659				
Routes	-.267	.064	.905			
Hazards	.337	-.218	.873	.84		
Energy	.315	-.123	-.563	.312	.7	
Wrecks	-.419	.583	-.591	.566	-.39	.681

Table J-2 1.

Measures of Variable Sampling Adequacy.

Total matrix sampling adequacy: .498

Hurricanes	.553
Ports	.556
Routes	.53
Hazards	.464
Energy	.627
Wrecks	.246

Bartlett Test of Sphericity - DF: 20 Chi Square: 43.067 P: .002

Table J-22.

Eigenvalues ● nd Proportion of Original Variance.

	Magnitude	Variance Prom
Value 1	3.023	.504
Value 2	1.537	.256
Value 3	.856	.143

Table J-23.

Eigenvectors.

	Vector 1	Vector 2	Vector 3
Hurricanes	.424	I-.135	-.644
Ports	.371	.505	-.291
Routes	-.534	-.022	-.327
Hazards	-.451	.086	-.603
Energy	.43	-.4	-.163
Wrecks	.092	.748	.053

Table J-24.
Unrotated Factor Matrix.

	Factor 1	Factor 2
Hurricanes	-.738	-.167
Ports	-.645	.626
Routes	.929	-.027
Hazards	.784	.107
Energy	-.748	-.495
Wrecks	-.161	.927

Table J-25.
Communality Summary,

	SMC	Final Estimate
Hurricanes	.655	.572
Ports	.659	.808
Routes	.905	.864
Hazards	.84	.626
Energy	.7	.805
Wrecks	.681	.884

Table J-26,
Orthogonal Transformation Solution-Varimax.

	Factor 1	Factor 2
Hurricanes	.753	.076
Ports	.412	.799
Routes	-.872	-.321
Hazards	-.777	-.148
Energy	.867	-.232
Wrecks	-.142	.93

Table J-27.
Oblique Solution Primary **Pattern** Matrix-Orthotran/Varlmsx.

	Factor 1	Factor 2
Hurricanes	-.795	-.079
Ports	-.114	.833
Routes	.822	-.179
Hazards	.792	.001
Energy	-1.051	-.46
Wrecks	.551	1.107

Table J-28.
Oblique Solution Reference Structure-Orthotran/Varimax.

	Factor 1	Factor 2
Hurricanes	-.675	-.067
Ports	-.097	.707
Routes	.698	-.152
Hazards	.672	.001
Energy	-.892	-.39
Wrecks	.468	.94

Table **J-29.**
Primary Intercorrelations-Orthotran/Varimax.

	Factor 1	Factor 2
Factor 1	1	
Factor 2	-.529	1

Table J-30,

Variable Complex ity-Orthotra n/Varlmax.

	Orthogonal	Oblique
Hurricanes	1.02	1.02
Ports	1.498	1.037
Routes	1.267	1.095
Hazards	1.072	1
Energy	1.142	1.369
Wrecks	1.047	1.467
Average	1.174	1.165

Table J-3 1.

Proportionate Variance Contributions.

	Orthogonal	Oblique		
	Direct	Direct	Joint	Total
Factor 1	.63	.663	.015	.678
Factor 2	.37	.429	-.107	.322

Table J-32.

Factor Score Weights for Oblique Transformation Solution-Orthotran/Va . . .

	Factor 1	Factor 2
Hurricanes	-.303	-.089
Ports	.113	.51
Routes	.265	-.069
Hazards	.288	.04
Energy	-.467	-.337
Wrecks	.405	.713

Table J-33.
Factor Score Weights for Orthogonal Transformation Solution- Varimax.

	Factor 1	Factor 2“
Hurricanes	.266	-.026
Ports	.073	.454
Routes	-.286	-.115
Hazards	-.268	-.016
Energy	.337	-.227
Wrecks	-.141	.589

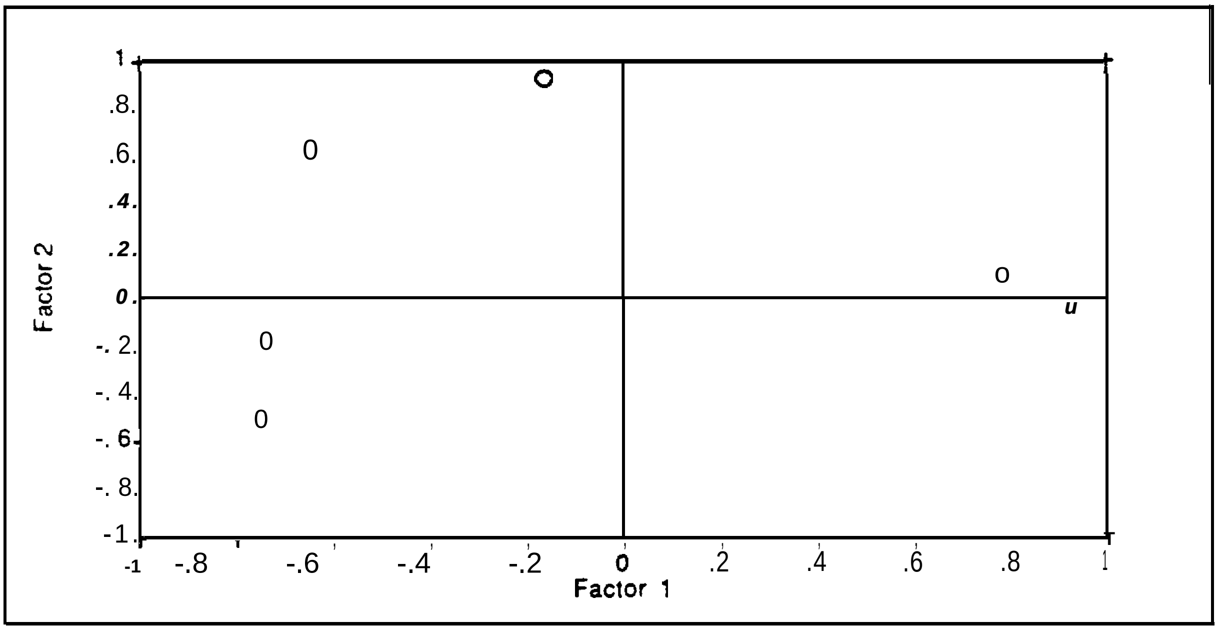

Figure J-10. **Unrotated** Orthogonal Plot: Factor 1 vs Factor 2.

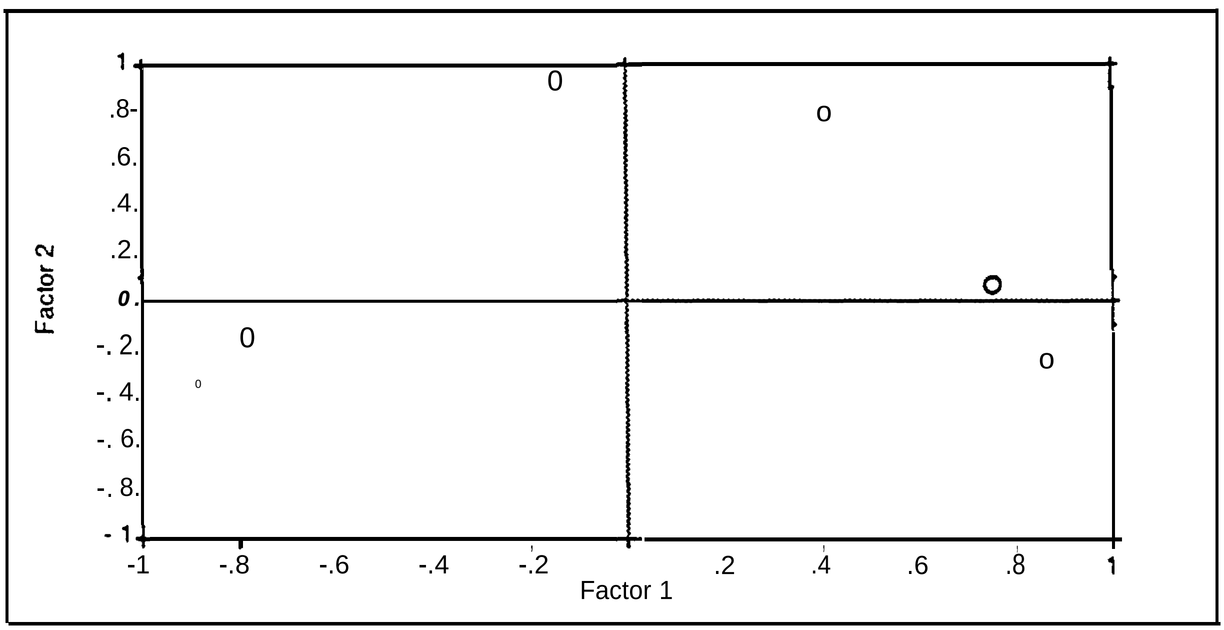

Figure J-11. Rotated Orthogonal Plot: Factor 1 vs Factor 2.

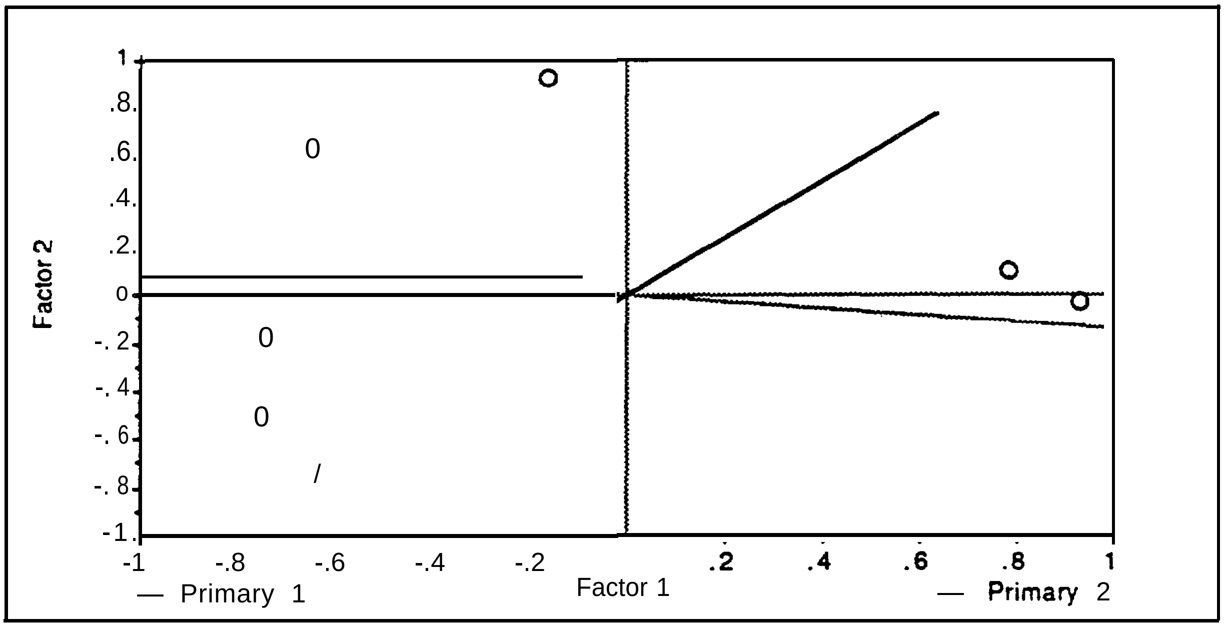

Figure J-12. Transformed Oblique Plot: Factor 1 vs Factor 2,

Table J-34.

Raw Data for Six Variables for Ten Areas, Northern Gulf of Mexico.

	Hurricanes	Ports	Routes	Hazards	Energy	Wrecks
1	10	1	2	0	3	3
2	10	2	2	0	3	12
3	10	6	2	0	1	27
4	5	2	3	3	2	15
5	15	4	3	2	2	6
6	13	1	3	2	3	4
7	4	0	3	0	0	6
8	4	2	3	0	2	6
9	4	1	4	5	0	4
10	4	0	4	5	0	17
11	•	•	•	•	•	•
12	•	•	•	•	•	•
13	•	•	•	•	•	•
14	•	•	•	•	•	•
15	•	•	•	•	•	•

1: Rio Grande; 2: Western Area; 3: Central Area; 4: Central Louisiana; 5: Miss./Alabama; 6: West Florida; 7: Big Bend; 8: Middle Ground; 9: Southwest Florida; 10: Dry Tortugas.

APPENDIX K

Ground Truthing Data

Groundtruthing Characterization of Side-Scan Sonar Contacts and/or Magnetic Anomalies: Instrumental and Observational Data

Site #1

1. Location: 101 GA 332/SP 107 (Read: "Line 101, Galveston Area Lease Block 332/Shot Point Number 107") 28° 47'54.91" N/95°. 09' 26.48" W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly

3. Instruments: EG & G, V Geometries G-866 proton magnetometor, Starfix Navigation

4. Magnetometer Cycle Time: 1.5 see; Scale = 1 00/1000 nt

5. Side-scan sonar range: -

6. Depth of water: 21 m (70 ft)

7. Depth of sensor: 16 m (52 ft)

8. Number of tracks: 3 logged; 9 total

9. Track spacins: 20 m (characterization); 50 m (survey)

10. Track directions: N-S

11. Vessel speed: 2.5 m/s (5 kts.)

12. Ground-truthed: yes

13. Documentation: Analog magnetometer and navigation records

14. Description: Point source anomaly with little duration (a). Steep gradient much like noise spike but during June 1988 relocation survey on two lines (b,c) was possible. Ground truthing in August 1988 was not able to relocate the object. Source unknown.

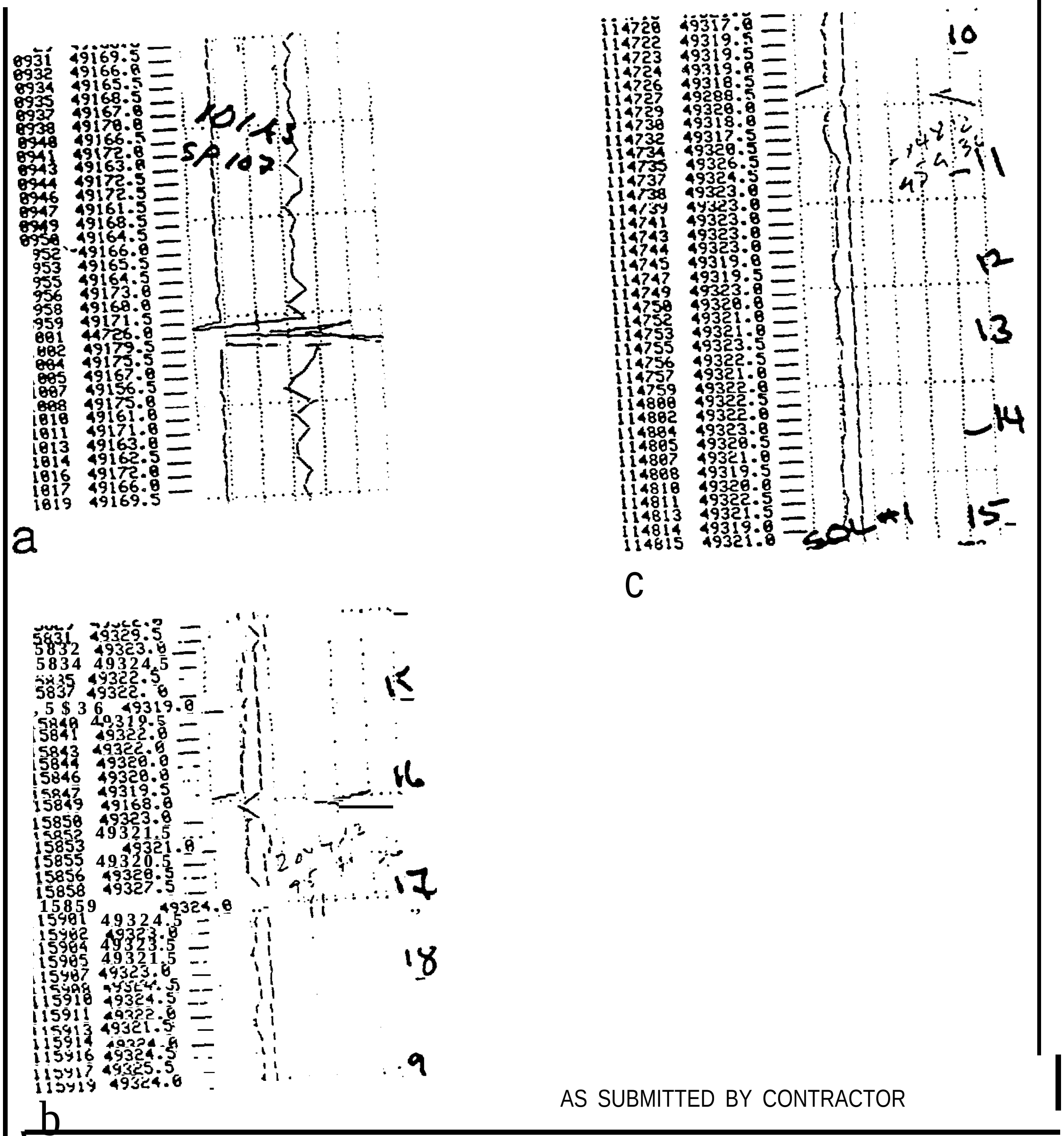

FIGURE K-1. Site #1 (a) resurvey anomaly (b,c) small anomaly detected during ground truthing.

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #2

1. Location: 107 GA 332/ SP 106 28° 45'45.09" N 95°09' 20.39" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly
3. instruments : EG & G, Geometries G-866 proton magnetometer, EG & G Geometries 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 s; scale = 100/1000 nt
5. Side-scan sonar ranae : 7 5 m
6. Depth of water: 21 m (70 ft)
7. Depth of sensor: 16 m (52 ft)
8. Number of tracks: 5 (logged); 13 total
9. Track spatins: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: yes
13. Documentalion: Analog and digital records of magnetometer and navigational data. Analog data for side scan sonar
14. Description: The steep magnetic gradient as shown in (a) was not repeated in relocation survey of the site (b,c). A relatively strong (50 nt) dipole feature (b) lies nearby smaller features (c) Groundtruth attempts did not locate any features above the sea floor. Metal detector readings were obtained by divers within a 60 meter diameter search circle, These contacts were of small and sharply localized; Depth to the sources was estimated as less than 0.5 meter. Probable Source: cable,

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #3

1. Location: 108 GA 332/ SP 106 28°47'57.16" N 95°09' 13.26 W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly

3. Instruments : EG & G Geometries G-866 proton magnetometer, EG & G Model 260 side scan sonar, Del Norte 542 Trisponder

4. Magnetometer Cycle Time; 1.5 see; scale: 1 00/1 000

5. Side-scan sonar ranae: 75 m

6. Depth of water: 21 m (70 ft)

7. Depth of sensor: 16 m (51 ft)

8. Number of tracks: 3 (total)

9. Track spating: 20 m (characterization); 50 m (survey)

10. Track directions: N-S

11. Vessel speed : 2.5 m/s (5 kts)

12. Ground-truthed: no

13. Documentation: analog magnetometer and side scan record.

14. Description: Block resurvey in March 1988 detected large anomaly with intense gradient (3a) that had an 8 second duration. The August resurvey found only a small (17 nt) anomaly (b) which was not at the original survey's coordinates. No attempt to groundtruth the anomaly was made. Probable Source: debris in anchorage area.

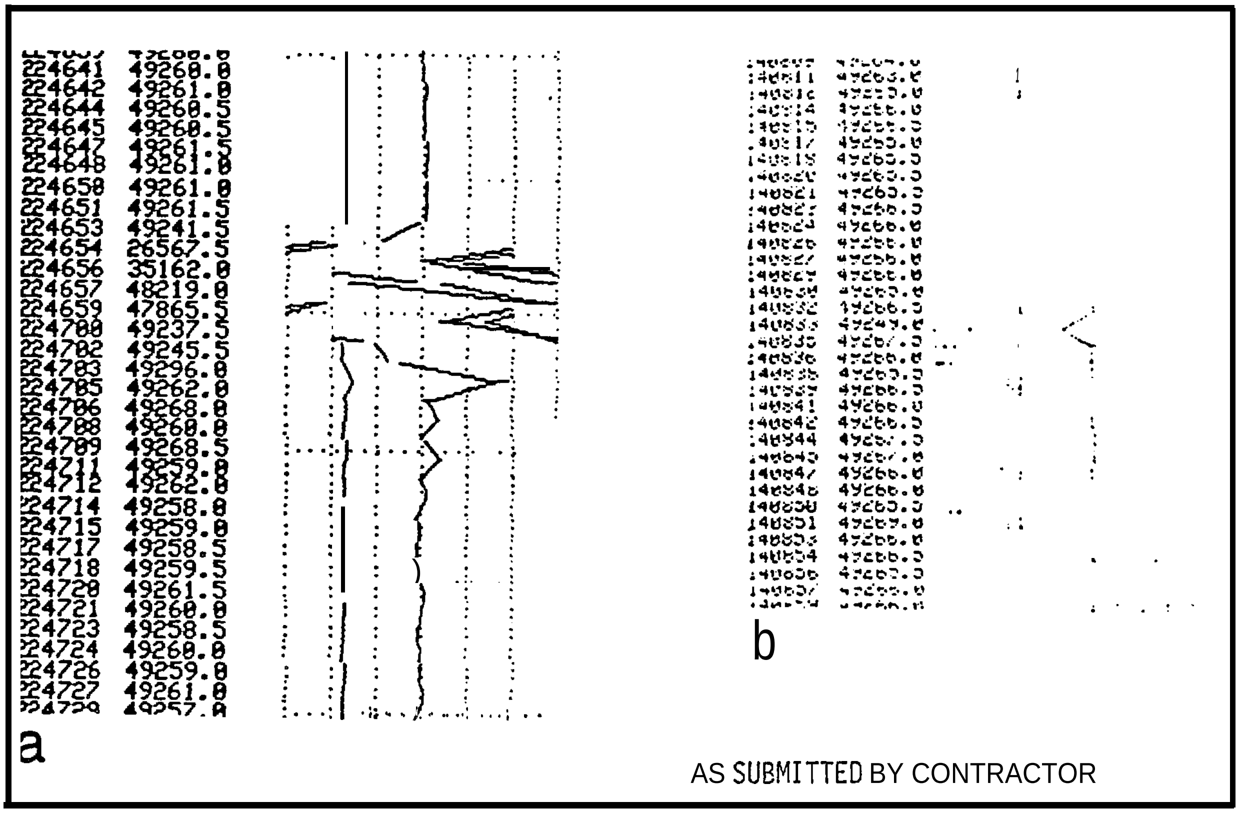

FIGURE K-3. **Site #3 (a) resurvey anomaly (b) anomaly detected during ground truthing.**

Characterization of Side Scan Sonar "Contacts and/or Magnetic Anomalies

Site #4

1. Location: 109 GA 332/ SP 103 28° 48'00.16" N 95° 09'11.45" W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly

3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G Model 260 side scan sonar, Del Norte 542 Trisponder

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: 75 m

6. Depth of water: 21 m(70 ft)

7. Depth of sensor: 16 m (50 ft)

8. Number of tracks: 1 (total)

9. Track spacins: 50 m (survey)

10. Track directions: S-N

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: no

13. Documentation: analog magnetometer and side scan sonar record

14. Description: Anomaly found in block resurvey was small (34 nt) monopole feature (a). The anomaly was not relocated. Source: unknown.

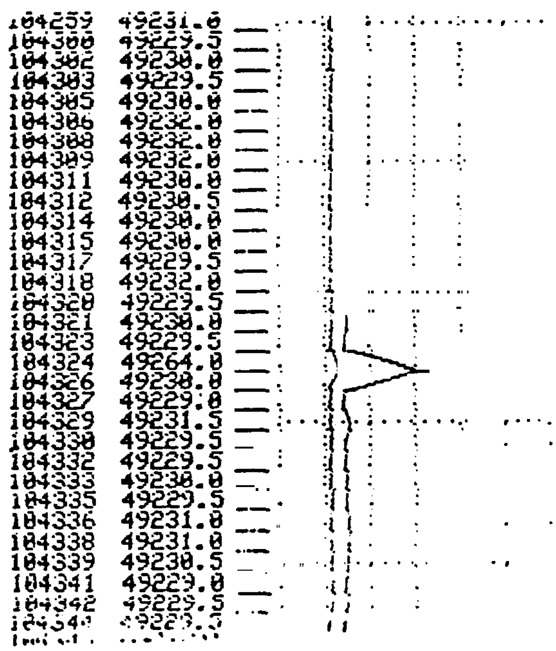

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FIGURE K-4, **Site** #4 **(a)** resurvey anomaly.

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #5

1. Location: 110 GA 324, SP 124-126 28° 45'7.20" N 94° 47'1.8" W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly

3. Instruments: EG & G Geometries G-866 proton magnetometer, Starfix navigation, EG & G 259-4 side scan sonar

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: -

6. Depth of water: 22 m(76 ft)

7. Depth of sensor: 15 m (48 ft)

8. Number of tracks: 3 logged

9. Track spatins: 20 m (characterization); 50 m (survey)

10. Track directions: N-S

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: yes

13. Documentation: Analog magnotometer, side scan sonar and navigation records

14. Description: Anomaly of small magnitude (-11 nt) but with 4.5-6.0 second duration (a, b). Small feature a shot point 9 on relocation survey line (c) and shot points 4 (d) are at the same coordinates. A narrow linear side scan sonar feature was seen at this point but it appears to be a trawl scar. Dives on these coordinates found nothing. Source: unknown.

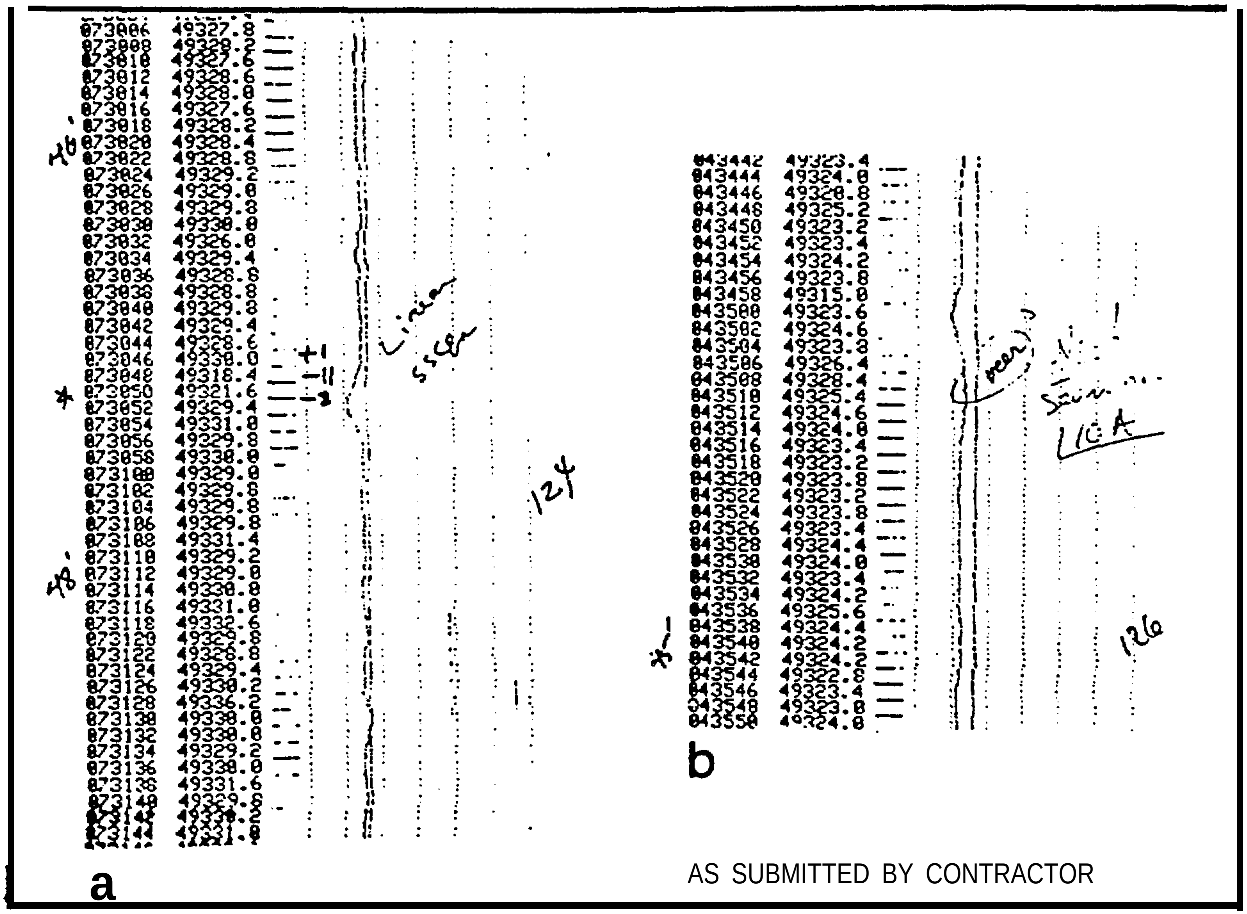

FIGURE K-5. **Site** #5 **(a,b) resurvey anomaly.**

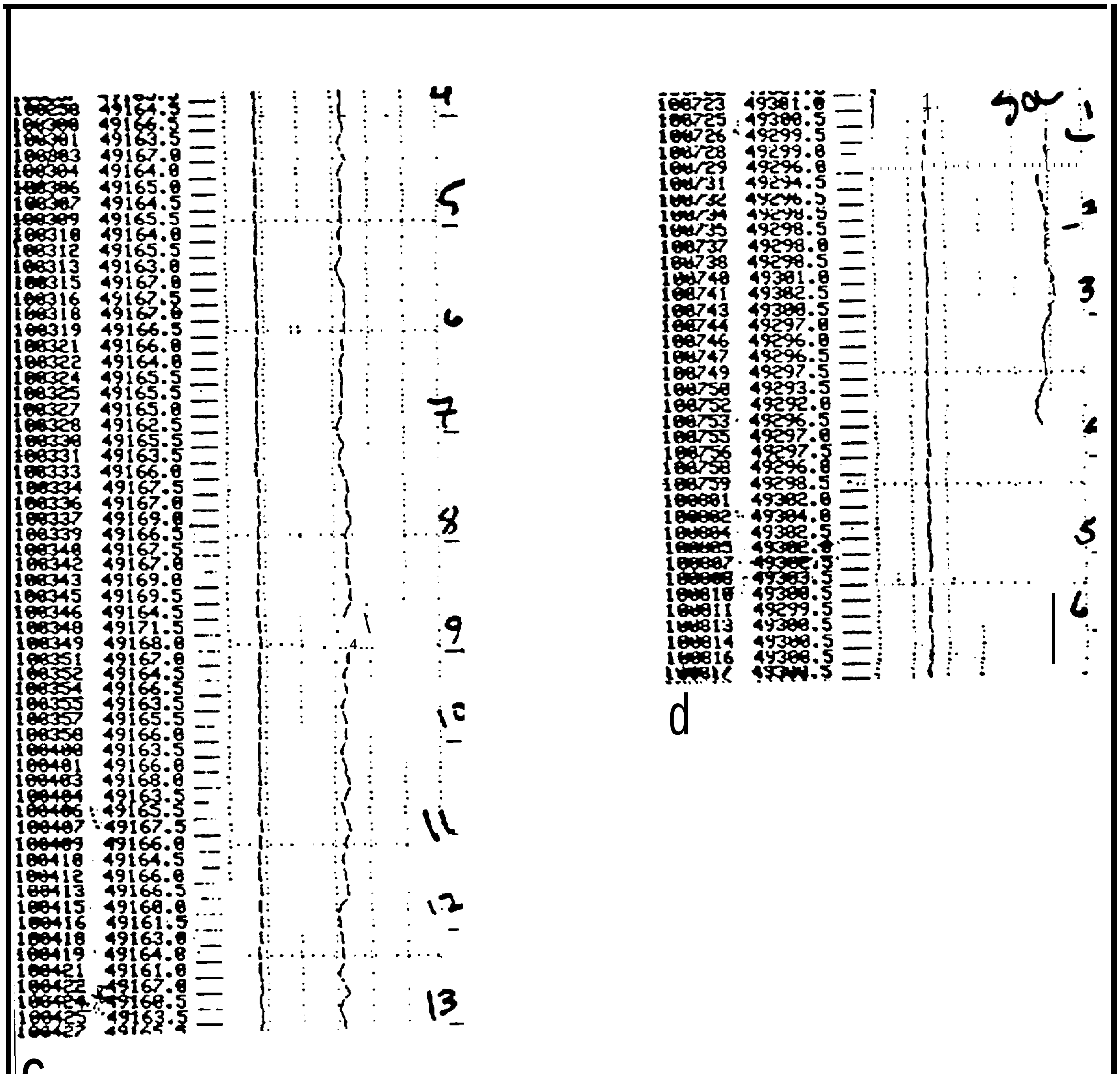

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FIGURE K-6. **Site #5 cont. - (c,d) magnetometer record of anomaly location during ground truthing.**

Characterization **of Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site #6

1. Location: 116 GA 332/ SP 128 28°46'49.5'95° 09'01.4"
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly
3. Instruments : EG & G Geometries G-866 proton magnetometer, Del Norte 542 Trisponder, EG & G 260 side scan sonar
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar ranae : 75 m
6. Depth of water: 21 m (70 ft)
7. Depth of sensor: 16 m (51 ft)
8. Number of tracks: 2 logged; 6 total
9. Track spacing: 10 m (characterization); 50 m (survey)
10. Track directions: N-S
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: no
13. Documentation: Analog-digital magnetometer and navigation data. Side scan sonar data is analog.
14. Desription: Anomaly is small feature (13 nt, 2 s amplitude & duration) (see a,b,c). No groundtruthing was attempted. Probable Source: ferric debris in anchorage area.

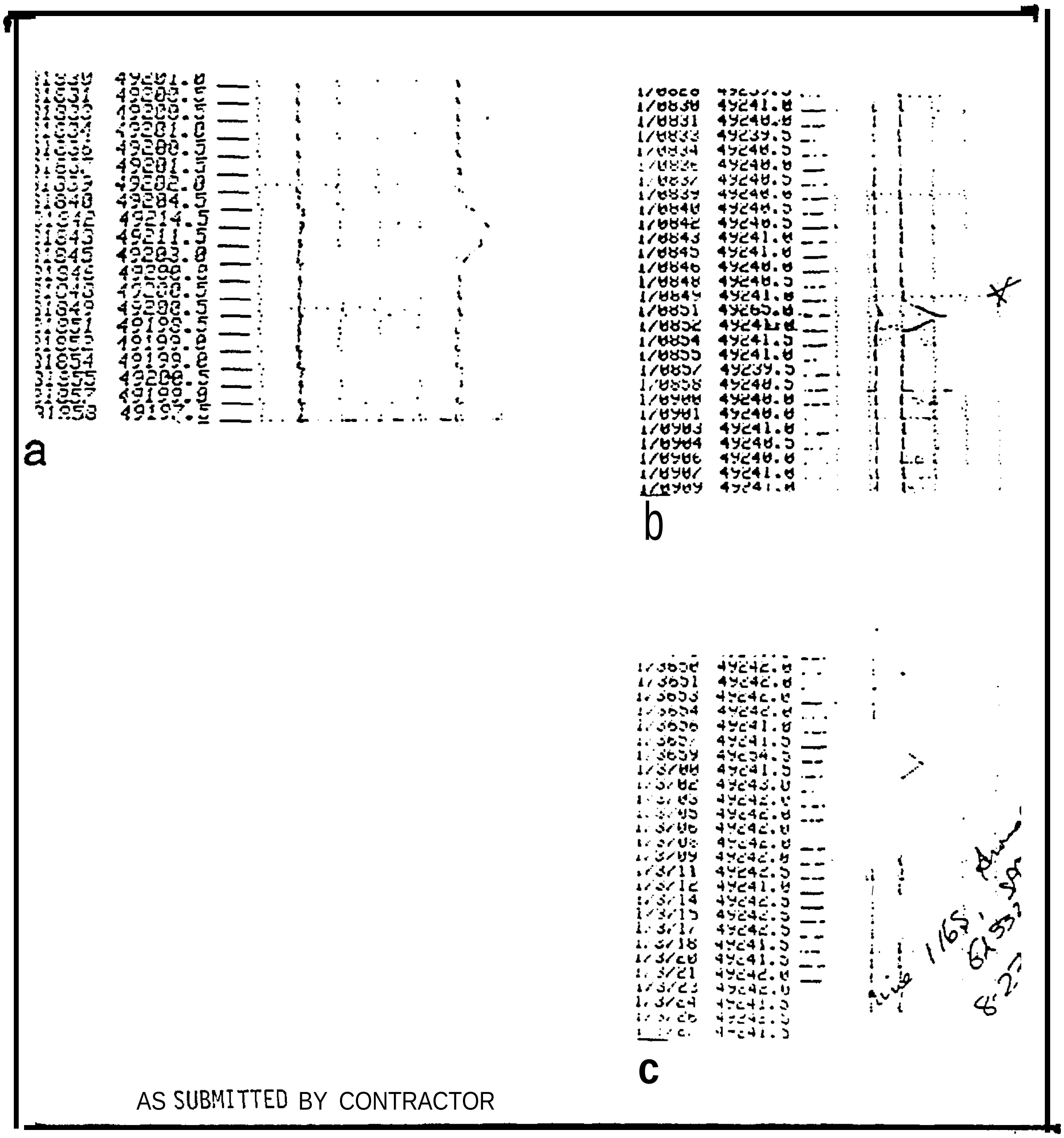

FIGURE K-7. **Site** #6 (a) **resurvey anomaly (b,c) anomaly detected during ground truthing.**

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #7

1. Location: 125 GA 332/ SP 156 28°48'10.85" N 95° 08'41.48" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic Anomaly
3. Instruments: EG & G Geometries G-866 proton magnetometer, Del Norte 542 Trisponder, EG & G 260 Side scan sonar
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range:-
6. Depth of water: 21 m (70 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 3 logged; 11 total
9. Track swatins: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts.)
12. Ground-truthed: yes
13. Documentation: Analog and digital magnetometer and navigation records. Side scan sonar
14. Description: Cluster of small anomalies scattered within 50-75 meter area. The features are small (ea. 20 nt) (b) with only brief duration (≤ 4.5 s) Ground truthing detected no features above the sea floor. Metal detector survey was negative. Probable Source: debris in anchorage area.

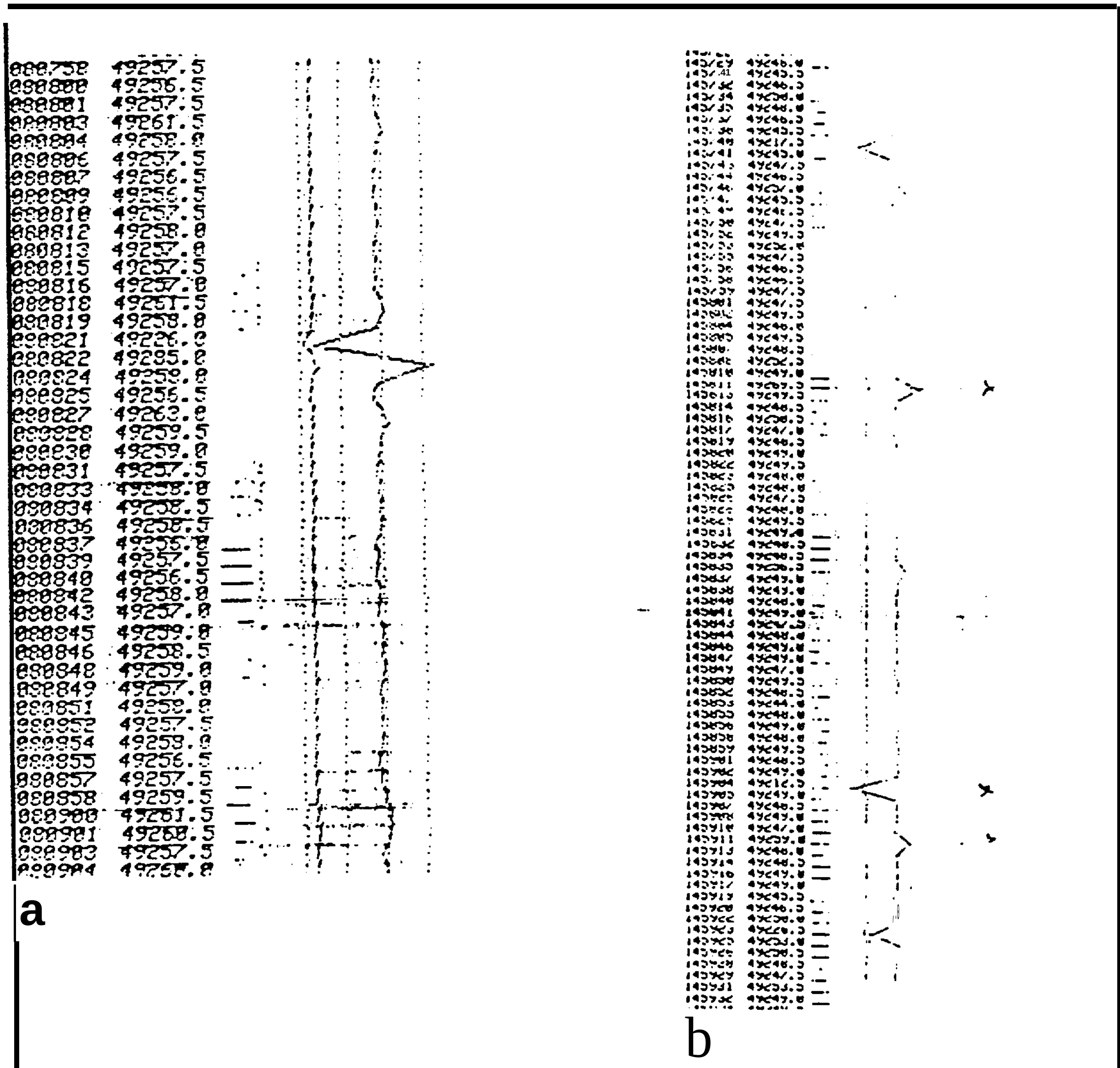

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FIGURE K-8. **Site #7 (a) resurvey anomaly (b) anomalies detected during ground truthing.**

Characterization **of Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site #8

1. Location: 137 GA 332/ SP 144 28° 47' 27.31 " N 95° 08'21.06" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly
3. Instruments : EG & G G-866 proton magnetometer, Del Norte 542 Trisponder, EG & G 260 side scan sonar
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20m (68 ft)
7. Depth of sensor: 15 m (51 ft) ?
8. Number of tracks: 3 logged; 5 total
9. Track spacins: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: no
13. Documentation: Analog and digital magnetometer and navigation data. Analog side scan **sonar records.**
14. Description: Dipolar feature (27, -30 nt) detected in block resurvey (a). This anomaly was seen on relocation/characterization survey (b, c). The maximum reading obtained during relocation was 29 nanoteslas (nt) which is in good agreement with the **resurvey data. Probable** Source: debris in anchorage area.

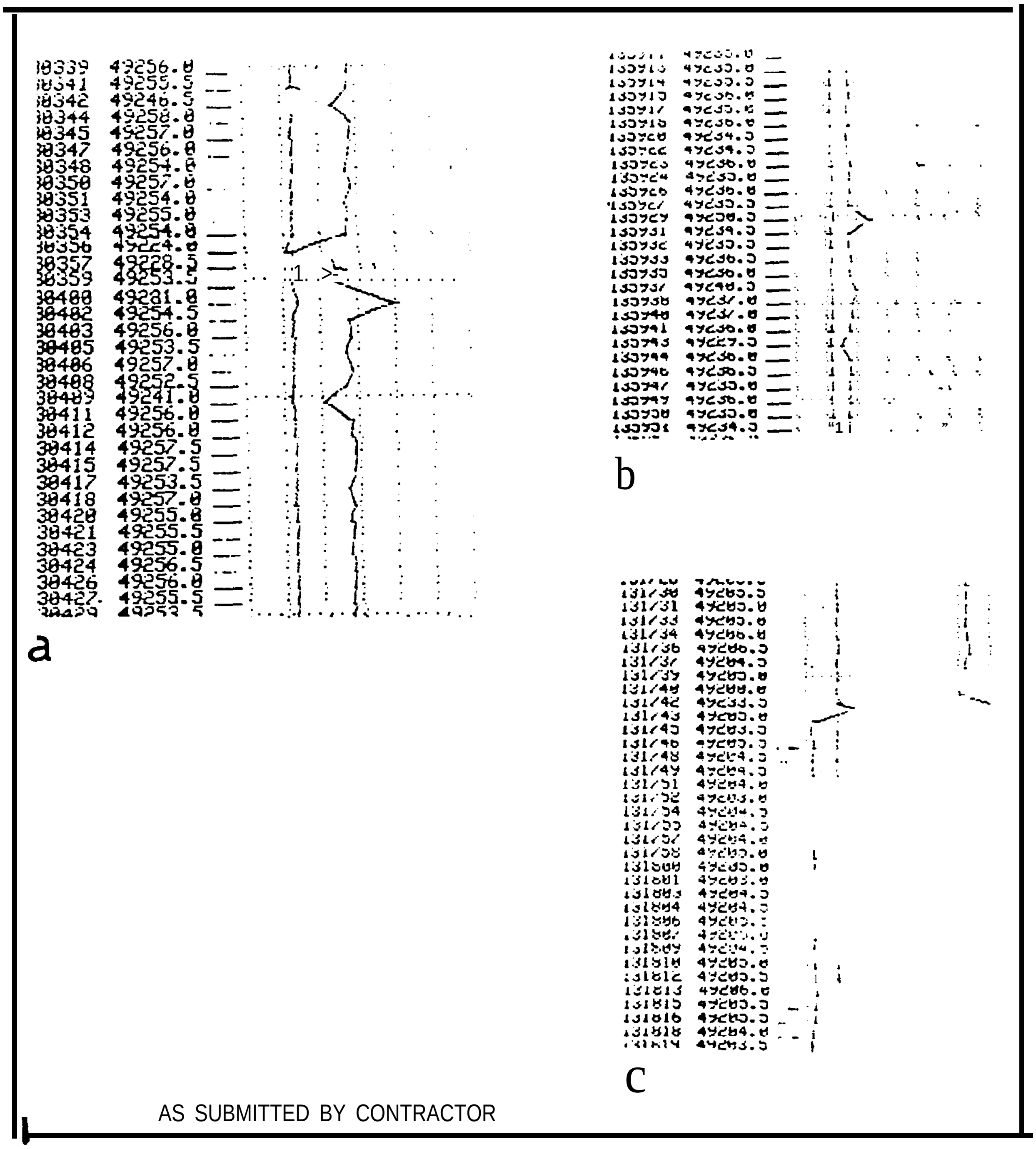

FIGURE K-9. Site #8 (a) **resurvey anomaly (b,c) anomaly detected during ground truthing.**

Characterization **of Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site #9

1. Location: 148 GA 332/ SP 106 28° 45'40.32" N 95° 08'4.24'" W
2. Type of Feature (Magnetic Anomaly and Side-Scan Sonar Contact): magnetic anomaly
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (68 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 3 logged; 6 total
9. Track spacing: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: no
13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar data.
14. Description: The sharp, strong feature (94 nt) seen on block resurvey (a) was relocated as a broad low amplitude feature (b) The anomaly was not groundtruthed. Probable Source: possible cable.

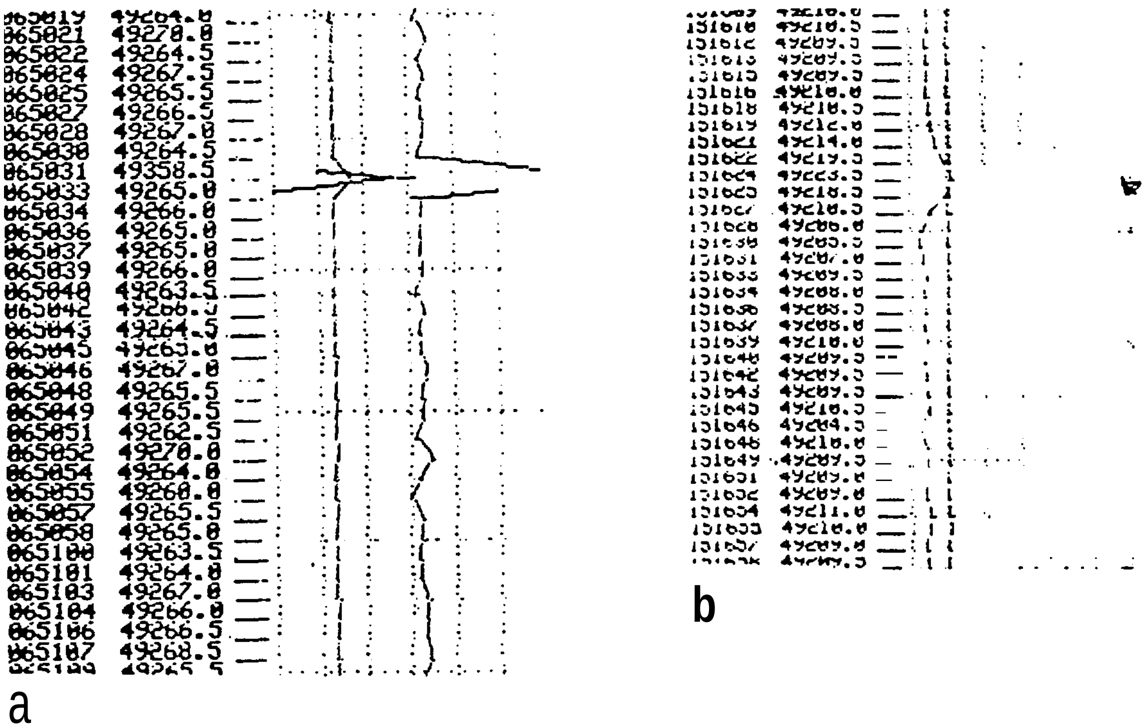

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FIGURE K-10. **Site #9** (a) **resurvey anomaly (b) anomaly detected during ground truthing.**

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #10

1. Location: 149 GA 313/ SP 106 28° 48'13.29" N 95° 07'57.13" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly and side scan sonar contact
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (67 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 7 total
9. Track spacing: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: no
13. Documentation: Analog magnetometer and side scan sonar data.
14. Description: Strong anomaly (a) detected on block resurvey not found on relocation. The anomaly shown in (b) is near these coordinates but was only detected on one line. Side scan sonar contact is interpreted as a trawl scar. Source: unknown.

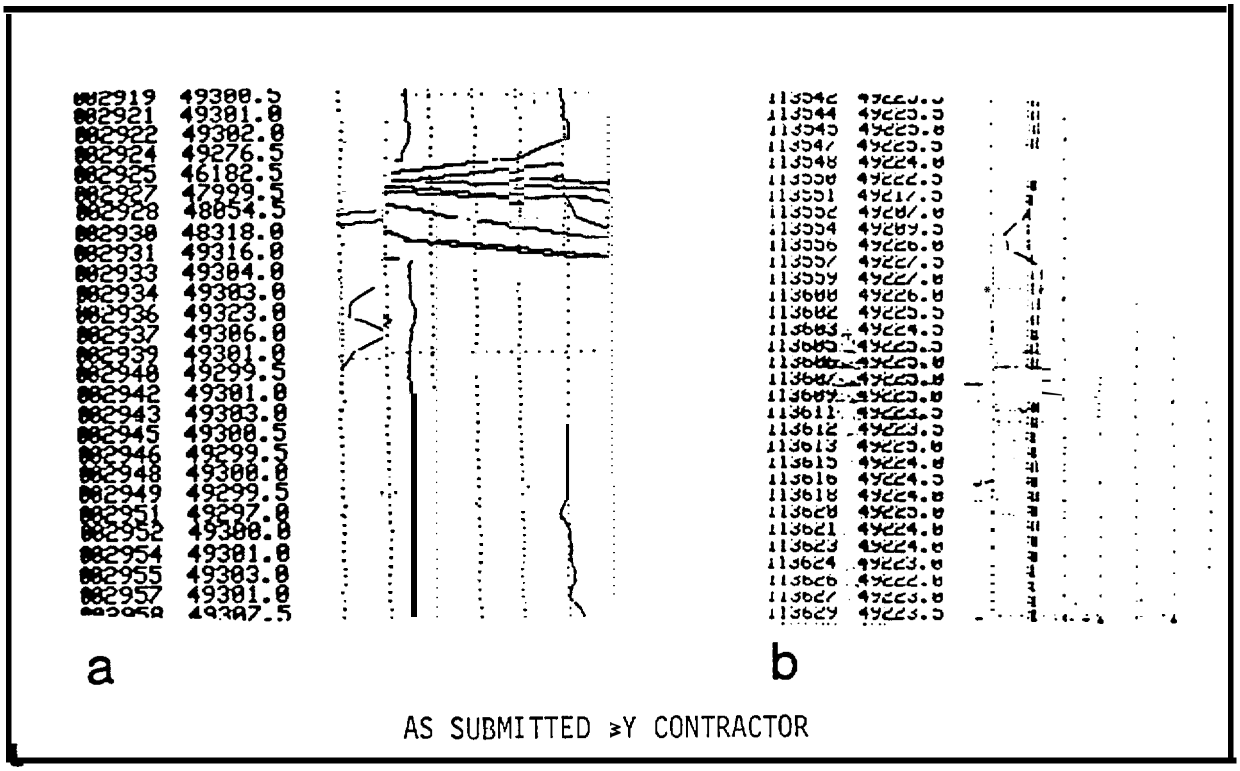

FIGURE K-11. Site #10 (a) resurvey anomaly (b) anomaly detected during ground truthing.

Characterization **of Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site #11

1. Location: 152 GA 313/ SP 11428° 48'39.75"N 95° 07,50.59" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly and side scan sonar
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (67 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 3 logged; 5 total
9. Track spacing: 10 m (characterization); 50 m (survey)
10. Track directions: N-S (4), E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: yes
13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar and bathymetry data.
14. Description: Originally located on block resurvey (a) as three large circular depressions with linear feature adjacent to them. Upon relocation a low amplitude monopolar anomaly was found (c, d). Divers relocated the features with the exception of a definite source for the magnetic anomaly. Source: scars from large jack-up rig. Depressions over 1.5 meters deep (b).

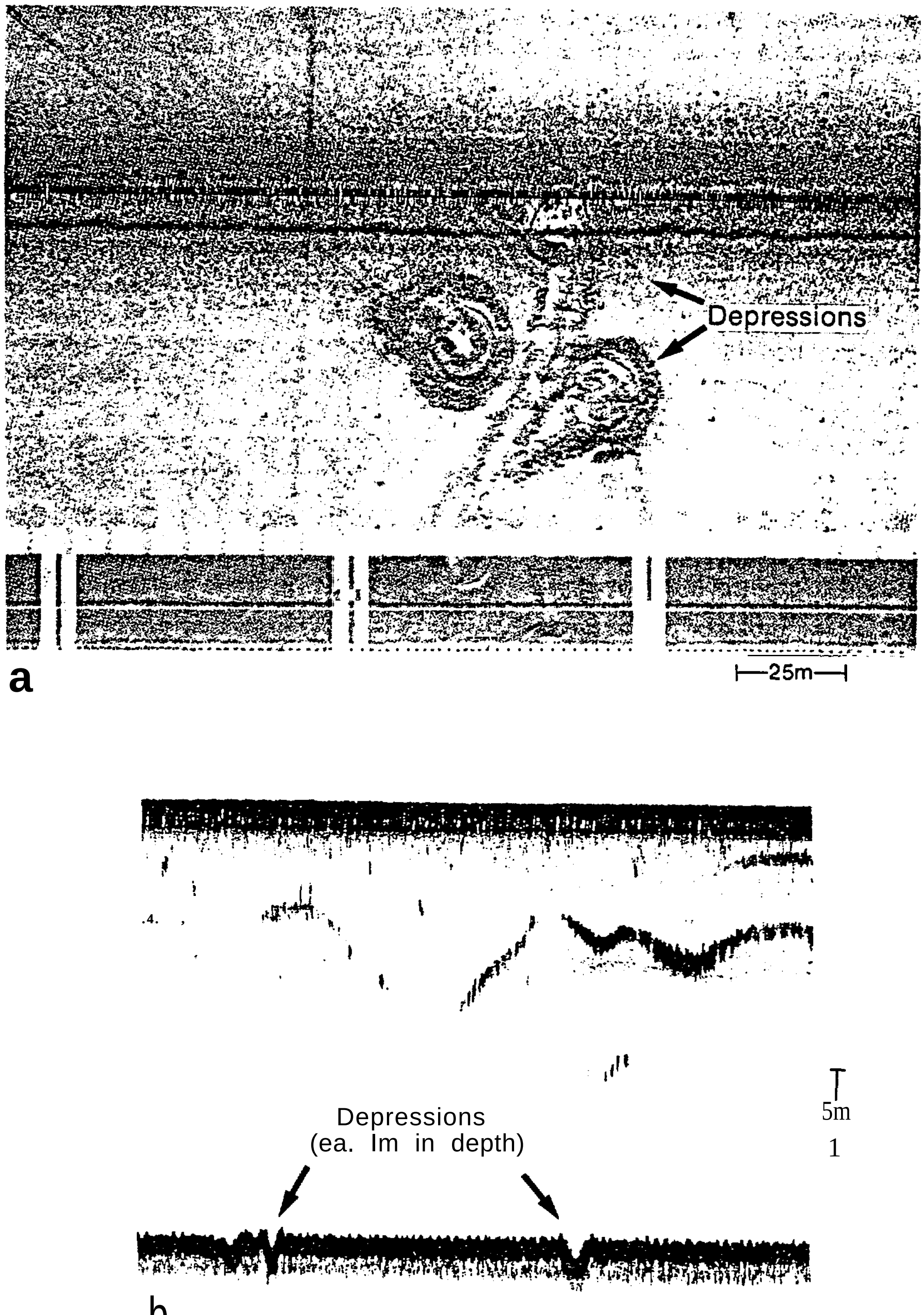

FIGURE K-12 Site #11 (a) sonograph of sea floor depressions found on resurvev: (b) fachometer record of depressions (2).

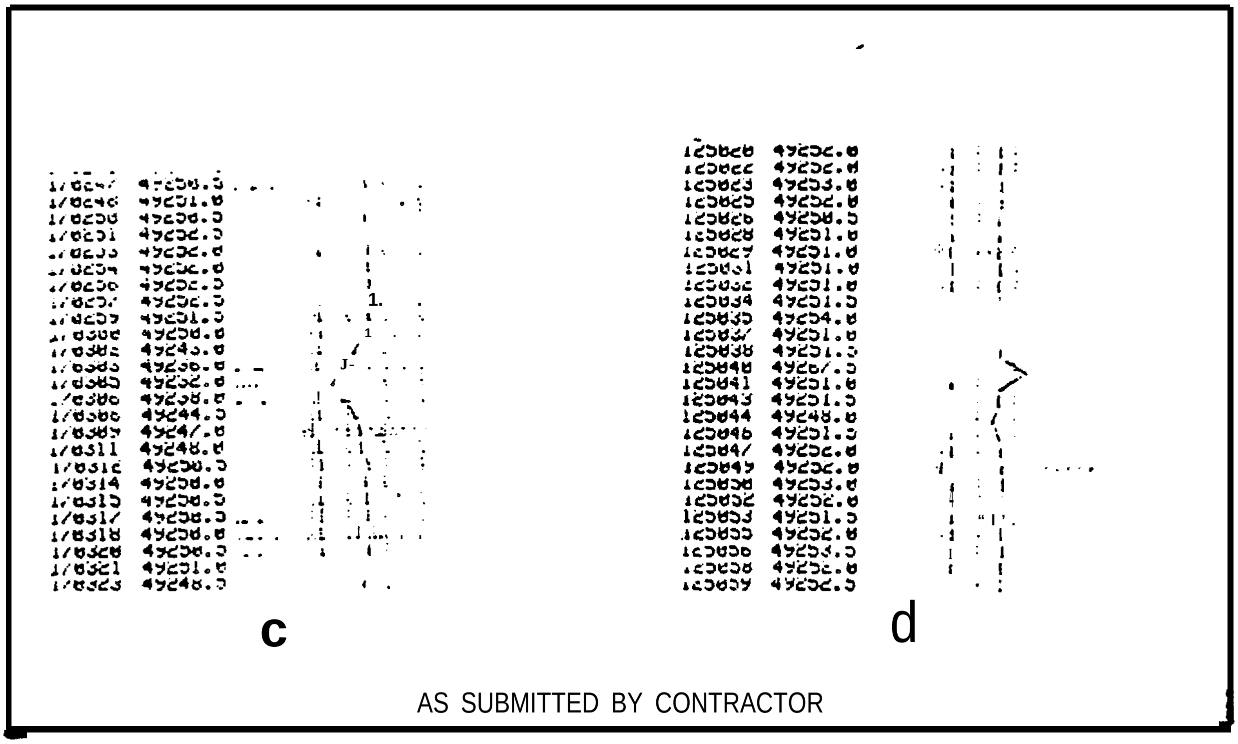

FIGURE K-13. **Site #11 cont. - (c,d) small** anomaly associated with sea floor depressions.

Characterization of **Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site **#12**

1. Location: 163 GA 313/ SP 16228°50’45.50” N 95°07’40.38” W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Side scan sonar

3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: 75 m

6. Depth of water: 20 m (66 ft)

7. Depth of sensor: 15 m (50 ft)

8. Number of tracks: 3 logged; 5 total

9. Track spacins: 10 m (characterization); 50 m (survey)

10. Track directions: N-S

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: yes

13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar data. Videotape of feature.

14. Description: 60+ meters linear feature with radiating depressions out to 100 meters (a). Small anomaly of 15 nt. Groundtruthing of feature found a shallow (≤ 50 cm) trench roughly 2 meters in width. No metal objects found to correlate to the observed anomaly. Probale Source: Ship anchor scar with “rays” the result of chain “chase”.

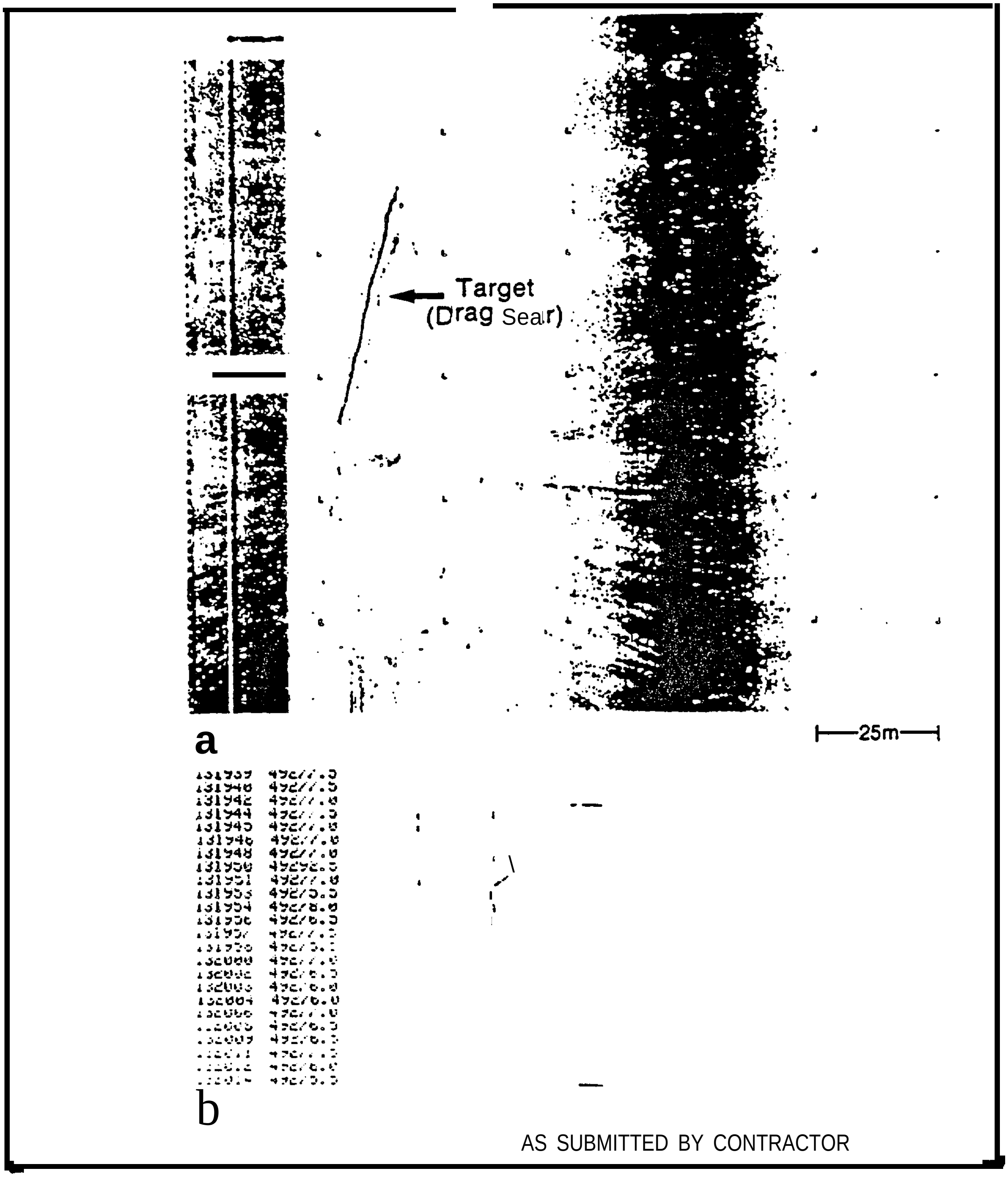

FIGURE K-14. Site #12 (a) sonograph of drag scar depression (b) associated (?) anomaly.

Characterization **of Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site #13

1. Location: 175 GA 313/ SP 12628°49’29.03” N 95° 07’06.38” N
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (66 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 3 logged; 7 total
9. Track spacing: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: yes
13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar data. Videotape of feature.
14. Description: Relatively broad (6 sec. duration), monopolar feature (a).This feature was relocated (b,c) and gave the same signature (shape). Divers found a buried strand **wire** cable. **Source: cable.**

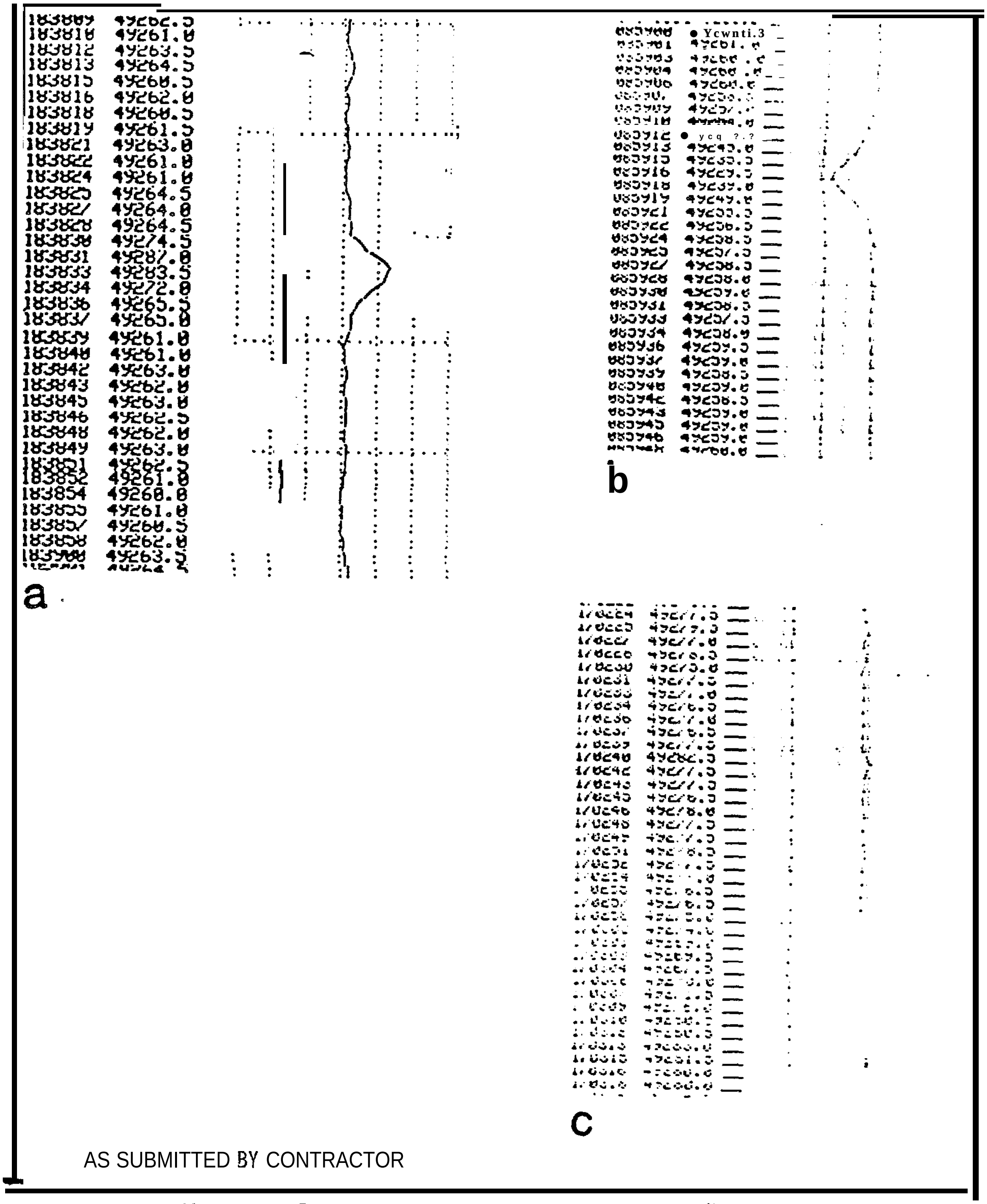

FIGURE K-15. **Site #13 (a) resurvey anomaly (b,c) anomaly detected during ground truthing.**

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #14

1. Location: 185 GA 313/ SP 145 28° 48'42.45" N 95° 06'49.79" W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly

3. Instruments : EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: 75 m

6. Depth of water: 20 m (66 ft)

7. Depth of sensor: 15 m (50 ft)

8. Number of tracks: 3 logged; 15 total

9. Track spacing: 10 m (characterization); 50 m (survey)

10. Track directions: N-S, E-W

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: yes

13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar data.

14. Description: Small cluster of anomalies (a) located during block resurvey. These were relocated on relocation surveys (b,c,d). One anomaly (b) is dipolar in shape. Groundtruthing was carried out within a 104 meter diameter area about the coordinates for the site. No anomalies could be relocated with metal detector. Source: unknown.

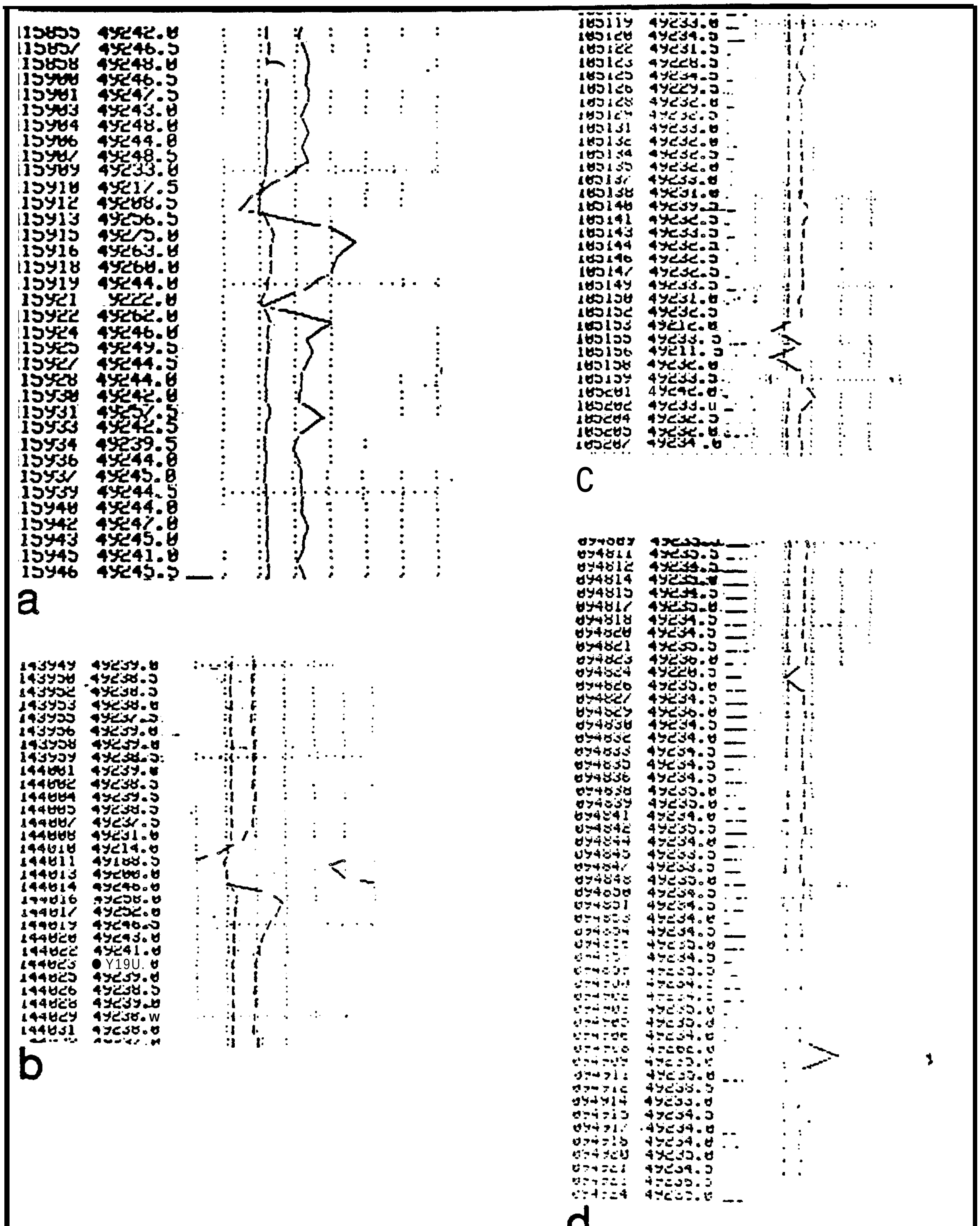

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FIGURE K-16. **Site #14 (a) resurvey anomaly (b-d) anomalies detected during ground truthing.**

Characterization **of Side Scan Sonar Contacts and/or Magnetic Anomalies**

Site #15

1. Location: 192 GA 313/ SP 11028°48'26.65" N 95° 06'37.27" W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): side scan sonar contact

3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, **Del** Norte 542 Trisponder

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: 75 m

6. Depth of water: 20 m (66 ft)

7. Depth of sensor: 15 m (50 ft)

8. Number of tracks: 3 total

9. Track spacing: 10 m (characterization); 50 m (survey)

10. Track directions: N-S

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: no

13. Documentation: Analog-digital magnetometer and side scan sonar **data.**

14. Description: A side scan sonar contact, (a) originally seen on the block resurvey, was relocated (b) and attempts **to** characterize the feature were made. A low amplitude anomaly (c) was located on 2 of 3 relocation tracks. Maximum deflection was 18 (nt). This anomaly could not be located to a precision necessary for groundtruthing. It's association with the side scan sonar contact was questionable as well. Source: unknown.

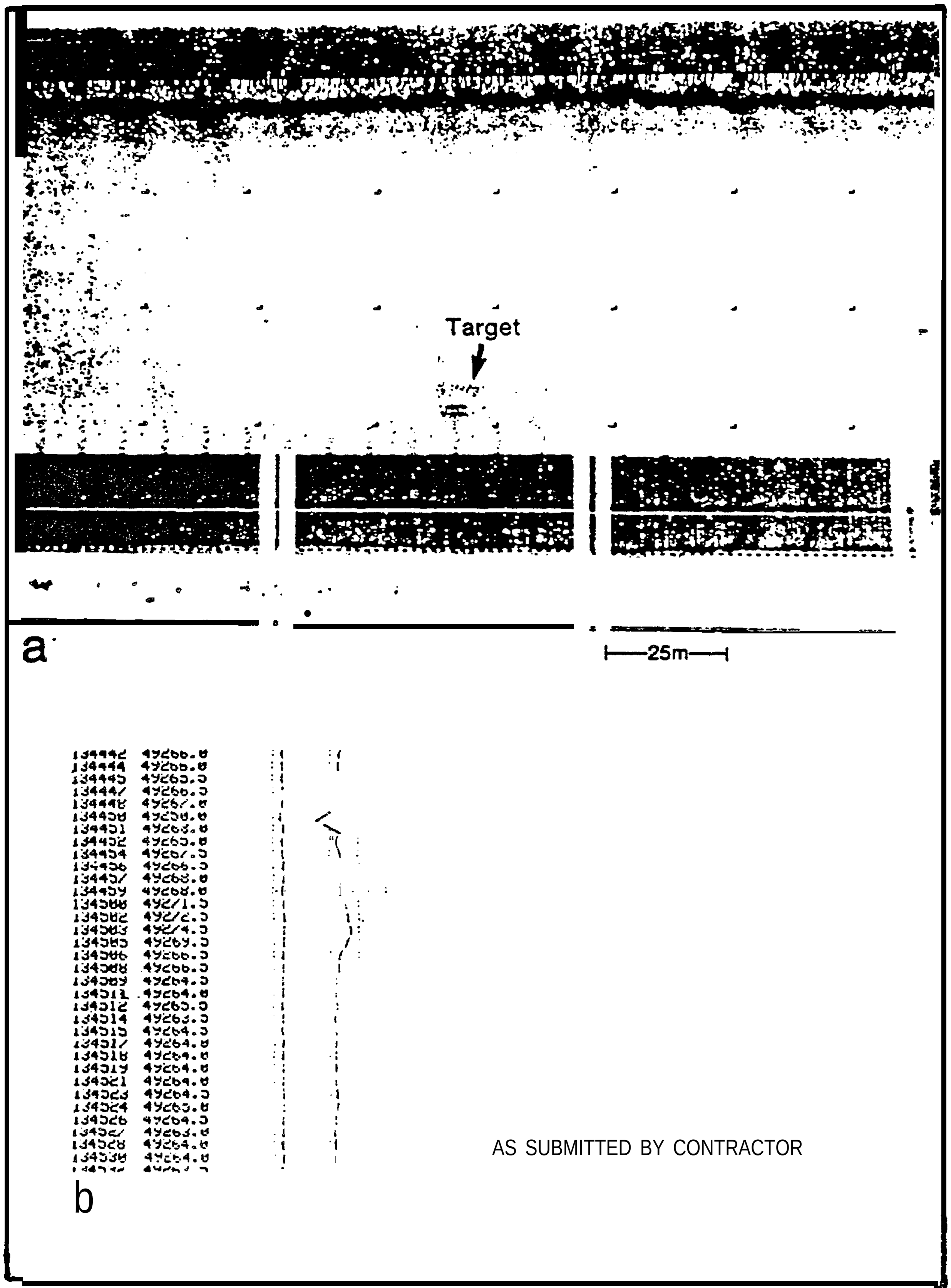

FIGURE K-17. **Site #15 (a) sonograph of resurvey contact (b) associated anomaly (?).**

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #16

1. Location: 194 GA 313/ SP 120 28°48'52.06" N 95°06'37.61 "W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly and side scan sonar contact
3. Instruments : EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (66 ft)
7. Depth of sensor: **15 m (50 ft)**
8. **Number of tracks: 2 total**
9. **Track spatings: 10 m (characterization);** 50 m (survey)
10. Track directions: N-S
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: no
13. Documentation: Analog magnetometer and side scan sonar data.
14. Description: A side scan sonar contact (c) and magnetic anomaly (a) found during block resurvey could **not be** relocated. A small anomaly (b) was found near this coordinate but no side scan contact was detected. Source: unknown.

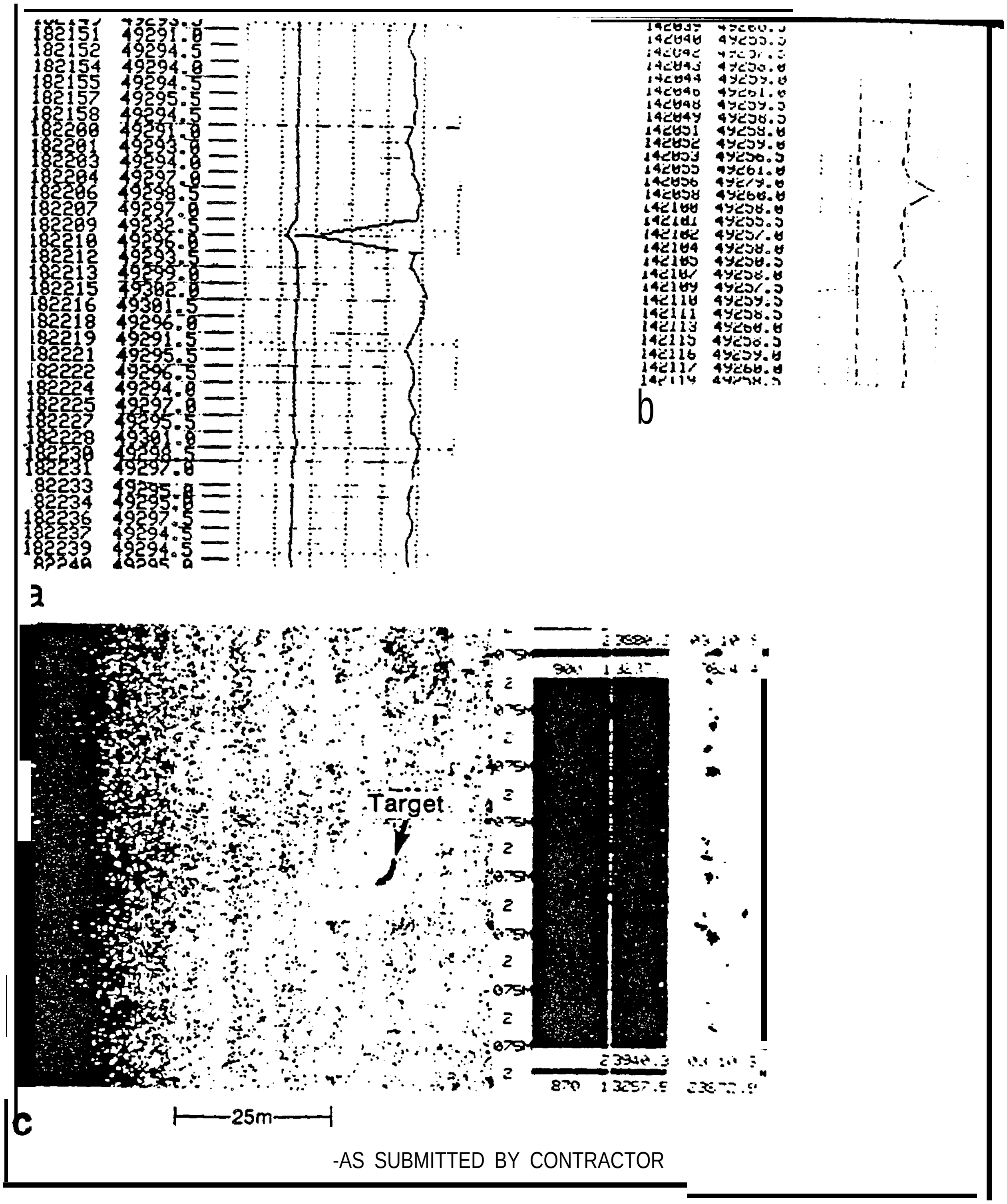

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FIGURE K-18. **Site #16 (a) resurvey anomaly (b)** anomaly detected during ground **truthing** (c) **sonograph** of resurvey contact.

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #17

1. Location: 197 GA 313/ SP 14728°48'41.48" N 95°06'27.54" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (66 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 2 total
9. Track spacing: 10 m (characterization); 50 m (survey)
10. Track directions: N-S
11. Vessel speed: 2.5 **m/s** (5 kts)
12. Ground-truthed: no
13. Documentation: Analog magnetometer and side scan sonar data.
14. Description: The magnetic anomaly (a) found during block resurvey could not be relocated. Source: unknown.

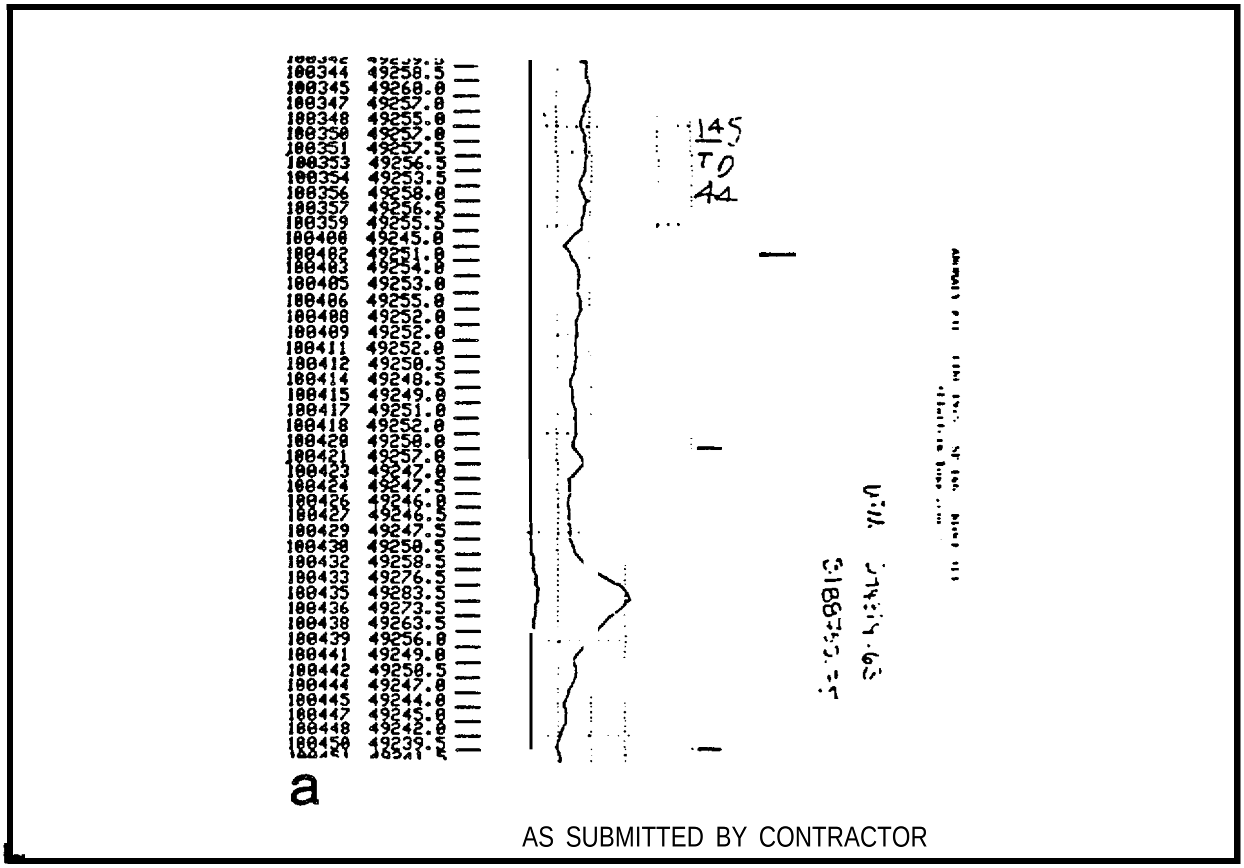

FIGURE K-19. Site #17 (a) resurvey anomaly.

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #18

1. Location: 202 GA 313/ SP 118 194403 N 3188498. E (UTM)
2. Type of feature: (Magnetic Anomaly and/or Stale-Scan Sonar Contact): Magnetic anomaly and side scan sonar contact
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder "
4. Magnetometer Cycle Time: 1.5 sec
5. Side-scan sonar range: 75 m
6. Depth of water: 20 m (66 ft)
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 3 logged; 10 total
9. Track spacing: 10 m
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: yes
13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar data. Videotape of the feature.
14. Description: A side scan sonar contact (a) and magnetic anomaly (b,c) were located during block resurvey near the existing production well SU-GA-313. The relocation survey confirmed this feature . The magnetic anomaly can be seen against the larger gradient of the platform (d,e). Source: two-door refrigerator.

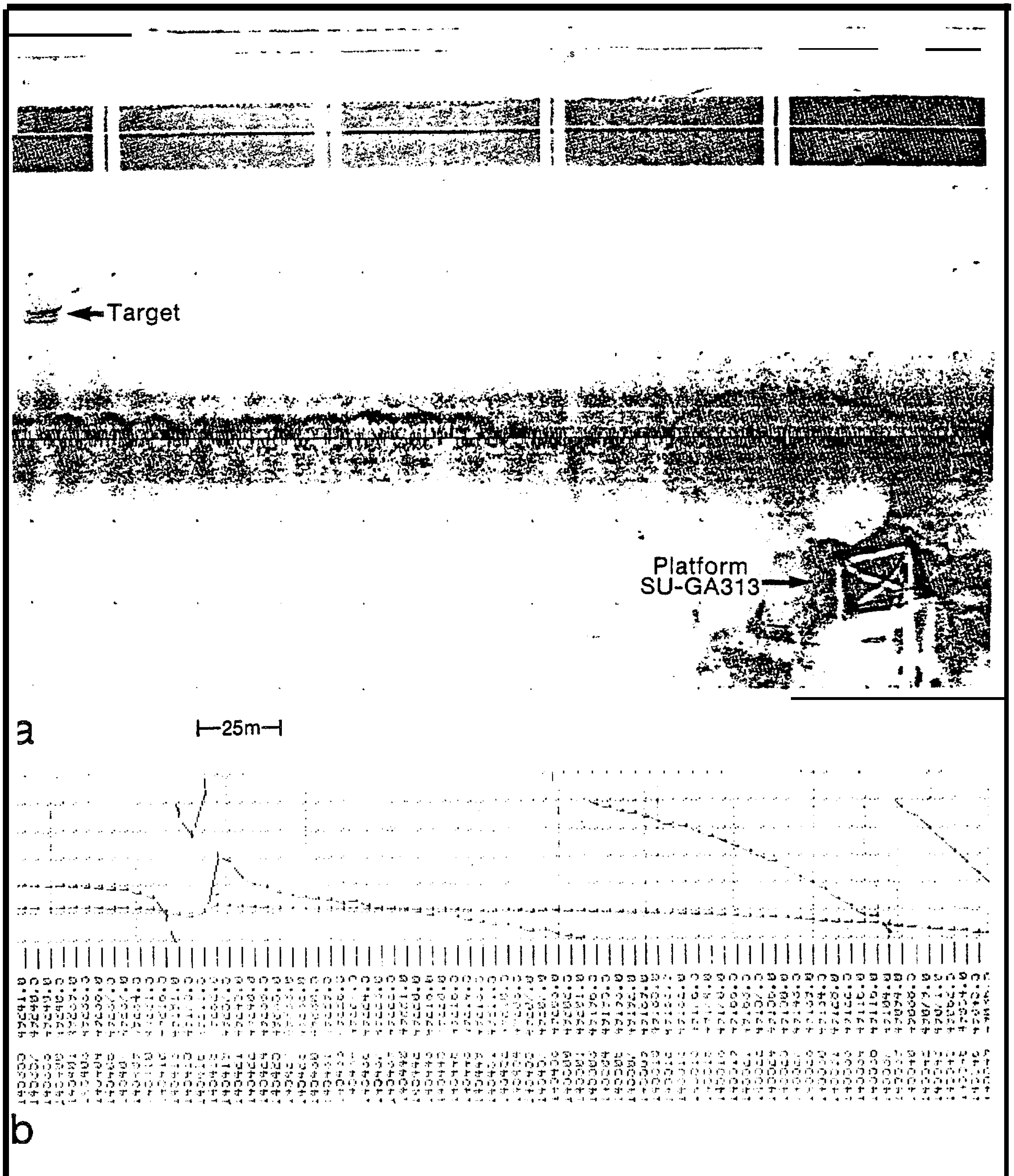

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FIGURE K-20 Site #18 (a) sonograph showing platform and toss zone feature; (b) anomaly detected during ground truthing (not platform's influence on local gradient).

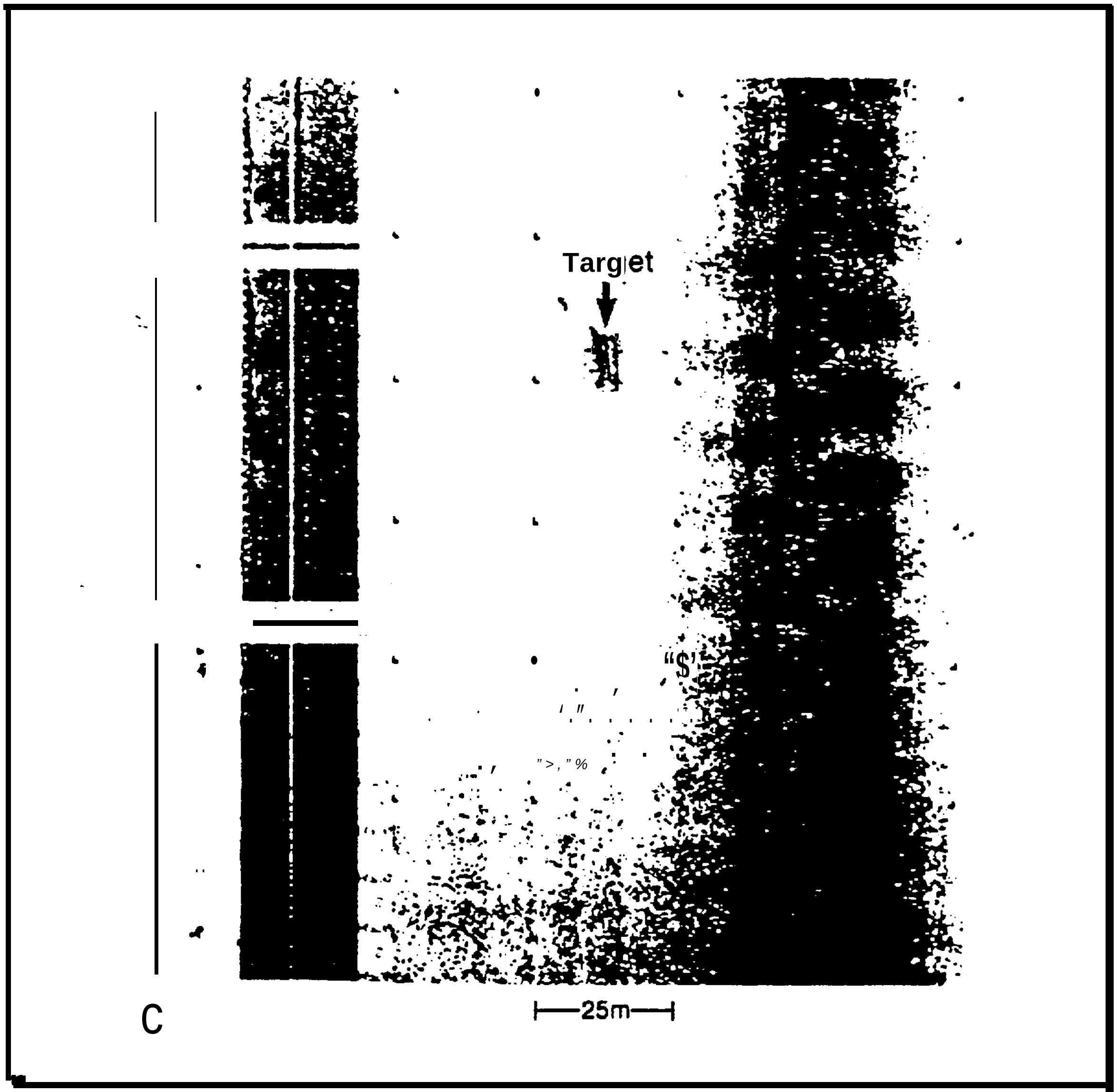

FIGURE K-21. Site #18 cont. - (c) sonograph of side scan contact (refrigerator).

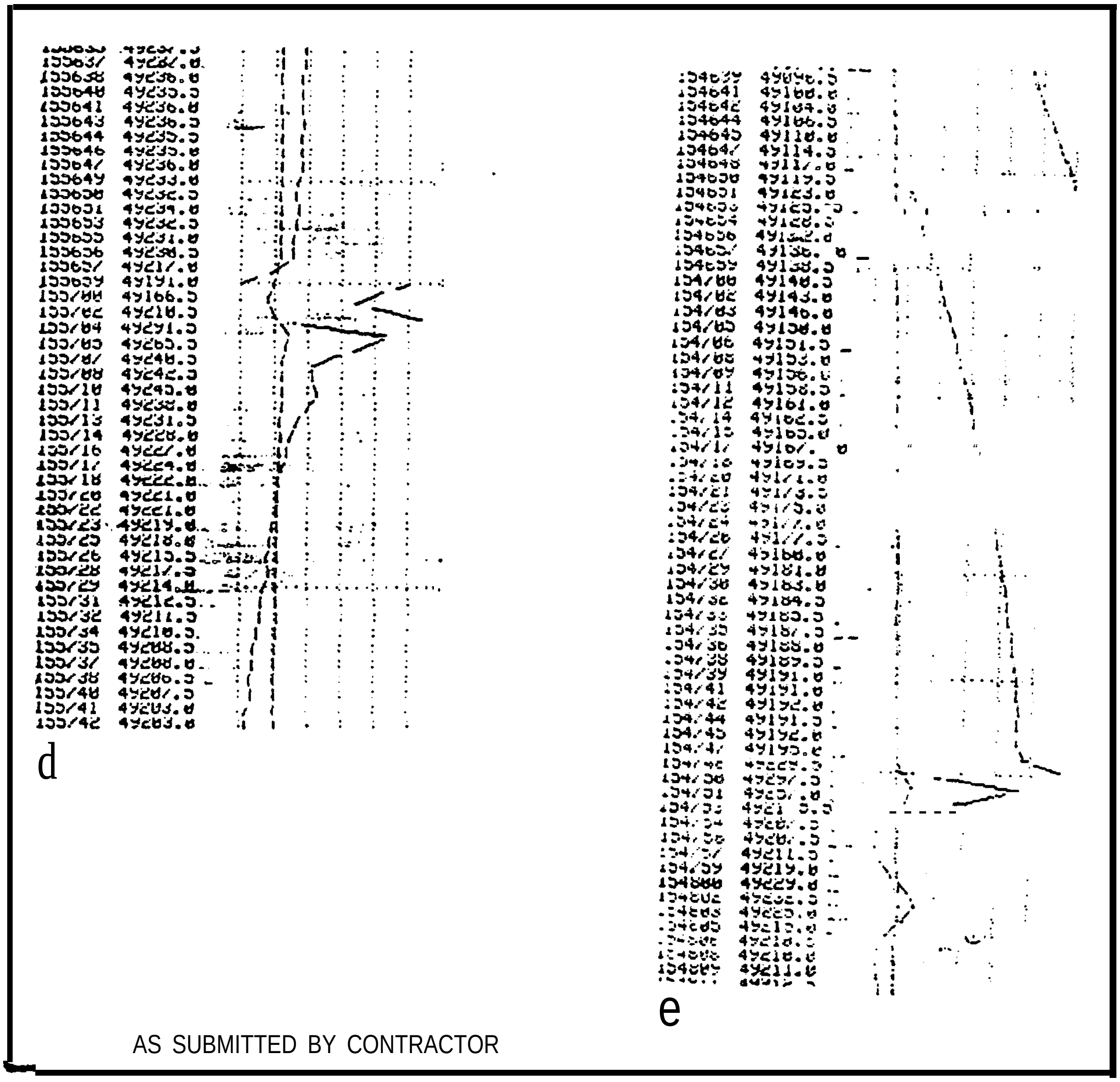

FIGURE K-22. **Site #18** cont. - **(d,e)** anomaly on 10 meter offset **lines either side** *of* **anomaly shown as (b).**

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #19

1. Location: 205 GA 313/ SP 115294719.84 N 3188838.5 E (UTM)

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly and side scan sonar contact.

3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: 75 m

6. Depth of water: 20 m (66 ft)

7. Depth of sensor: 15 m (50 ft)

8. Number of tracks: 3 logged; 4 total

9. Track spacing: 10 m

10. Track directions: N-S(4), E-W

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: yes

13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar data. Videotape of the feature.

14. Description: The site is two features termed "A" and "B". 205A is believed to be the same icebox located between lines 202 and 203. This feature more correctly lies between 203 and 204. The icebox was 38 meters from 205B whose characteristics as an anomaly are dipolar with some duration (a,b) and whose sonogram shows some relief (≤ .5 m). Divers identified a 55 gal. drum as the principal source for 205B.

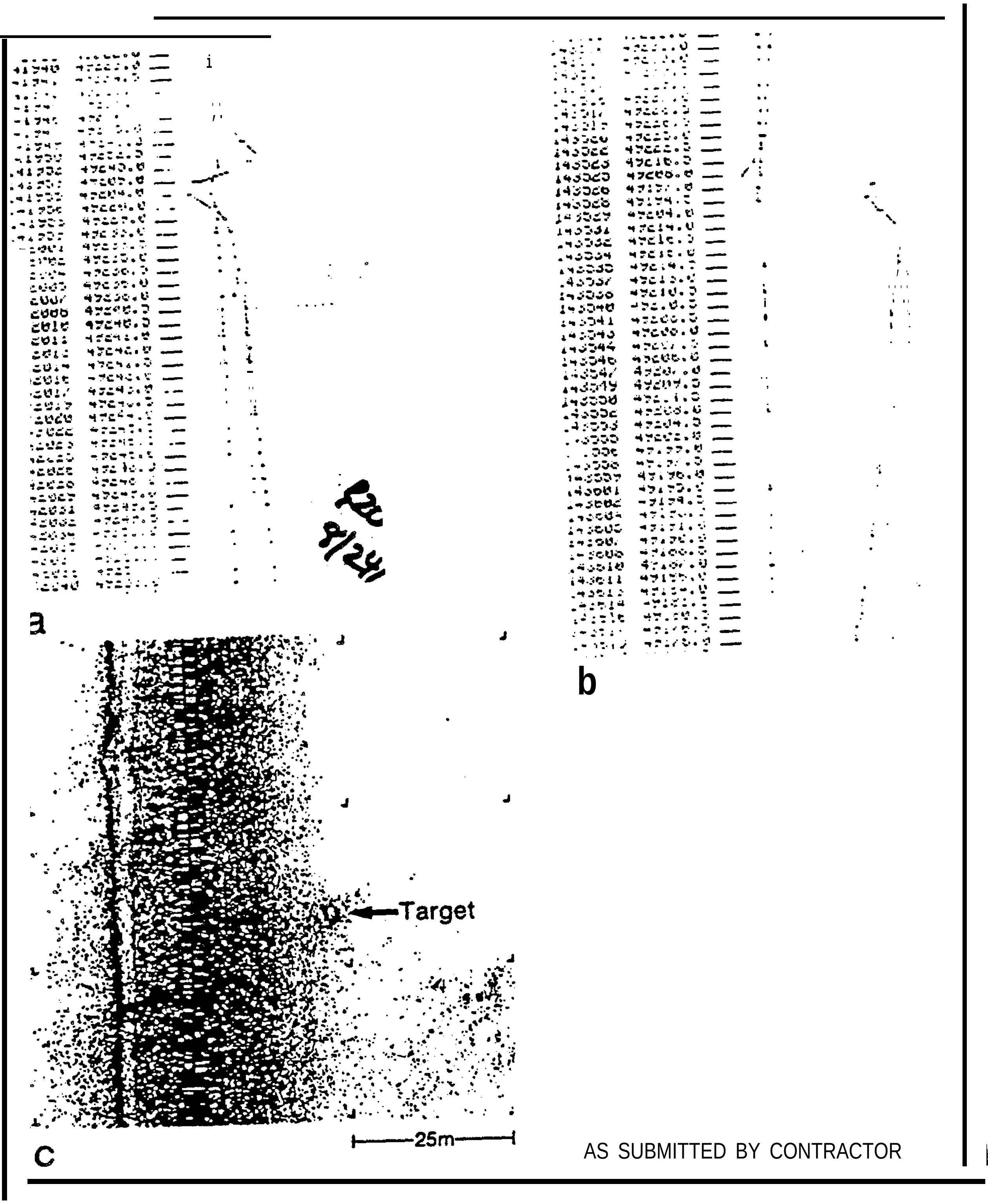

FIGURE K-23. **Site #19 (a,b)** anomaly associated with side scan sonar contact (c).

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #20

1. Location: 207 GA 313/ SP 147294814.56 N 3188891.25 E (UTM)
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Side scan sonar contact and magnetic anomaly
3. Instruments: EG & G Geometries g-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time : 1,5 sec
5. Side-scan sonar ranae: 75 m
6. Depth of water: 20 (66 ft)
7. Depth of sensor: 15 (50 ft)
8. Number of tracks: 3 logged; 10 total
9. Track spacins: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: yes
13. Documentalion: Analog-digital magnetometer and navigation data. Analog side scan sonar data. Videotape of the feature.
14. Description: Feature was found in resurvey near present production platform.. The signature shows classic dipolar shape (a,b) and diminishes rapidly with distance (c), where 30 meters reduces the amplitude to ambient field strength. Divers found a 55 gallon barrel, a bucket and beer cans near the target shown in (d).

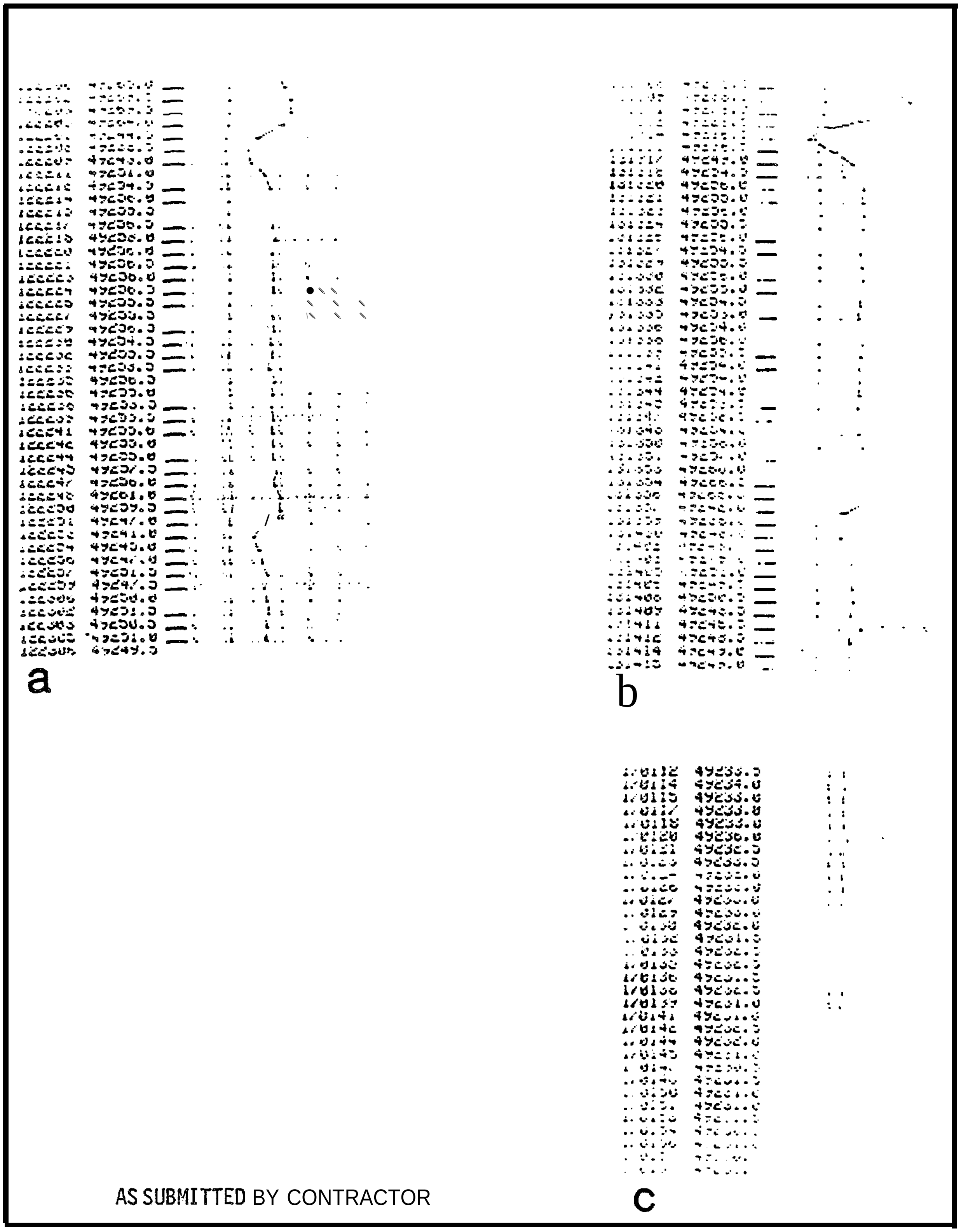

FIGURE K-24. **Site** #20 (a-c) anomaly detected on adjacent 10 **meter survey** lines, **(c)** represents 30 meter **distance from anomaly.**

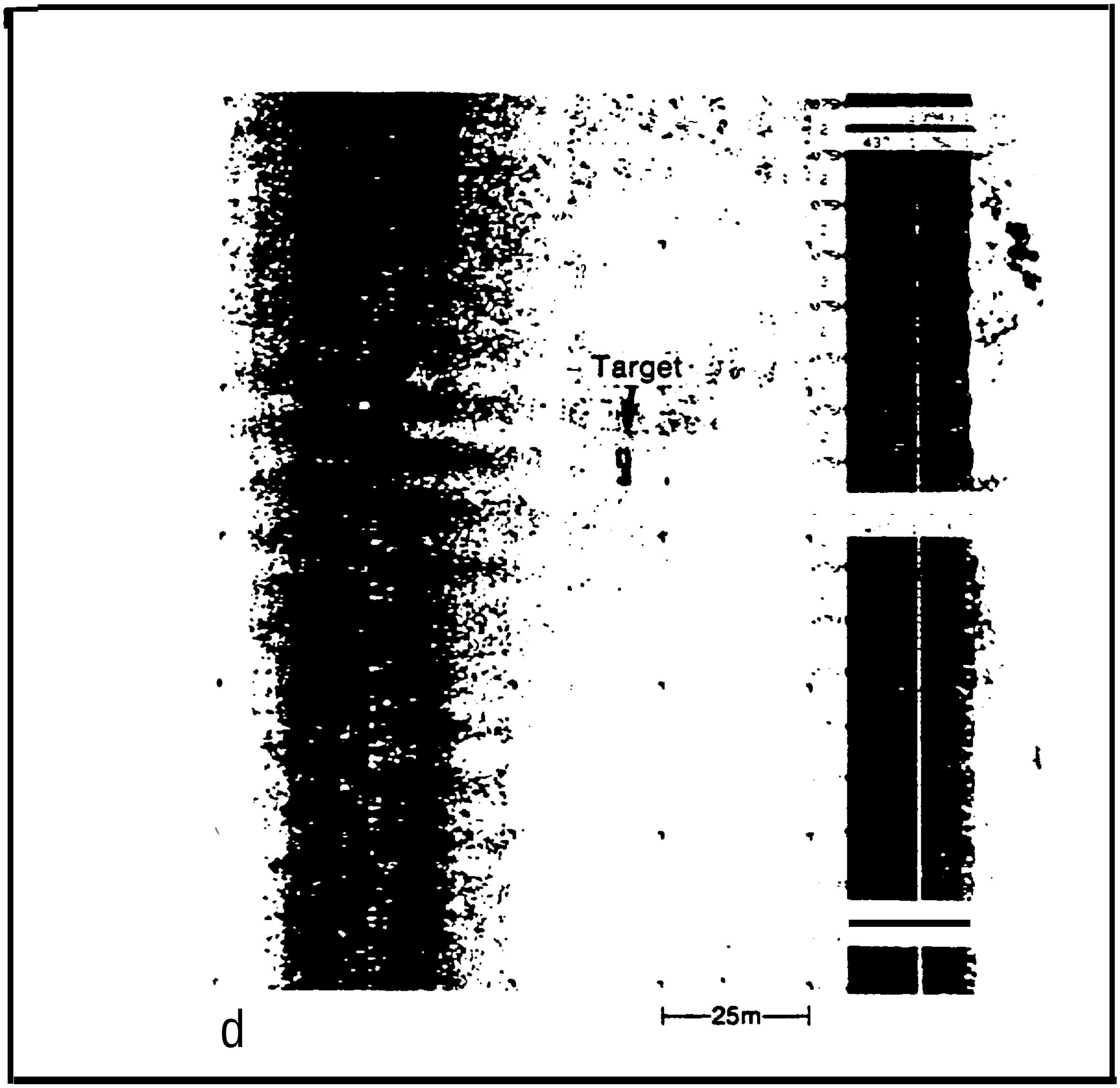

FIGURE K-25, Site#20 cont. - (d) sonograph of contact (barrel).

Characterization of Side Scan Sonar Contacts and/or Magnetic Anomalies

Site #.21

1. Location: 229 GA 313/ SP 10828°48'20.34" N 95°05'29.39" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly
3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder
4. Magnetometer Cycle Time: **1.5 sec**
5. **Side-scan sonar ranae: 75 m**
6. **Depth of water: 20 m (66 ft)**
7. Depth of sensor: 15 m (50 ft)
8. Number of tracks: 5 logged; 15 total
9. Track spacina: 10 m (characterization); 50 m (survey)
10. Track directions: N-S, E-W
11. Vessel speed: 2.5 m/s (5 kts)
12. Ground-truthed: yes
13. Documentation: Analog-digital magnetometer and navigation data. Analog side scan sonar.
14. Description: Feature found on block resurvey (a) is strong, broad dipolar anomaly. Relocation verified this (b,c) shape and strength for the anomaly with a gradual fall off 20 meters from the maximum deflection **seen (d). Divers located a buried pipe 5.8 meters** in length and 15-20 cm in diameter.

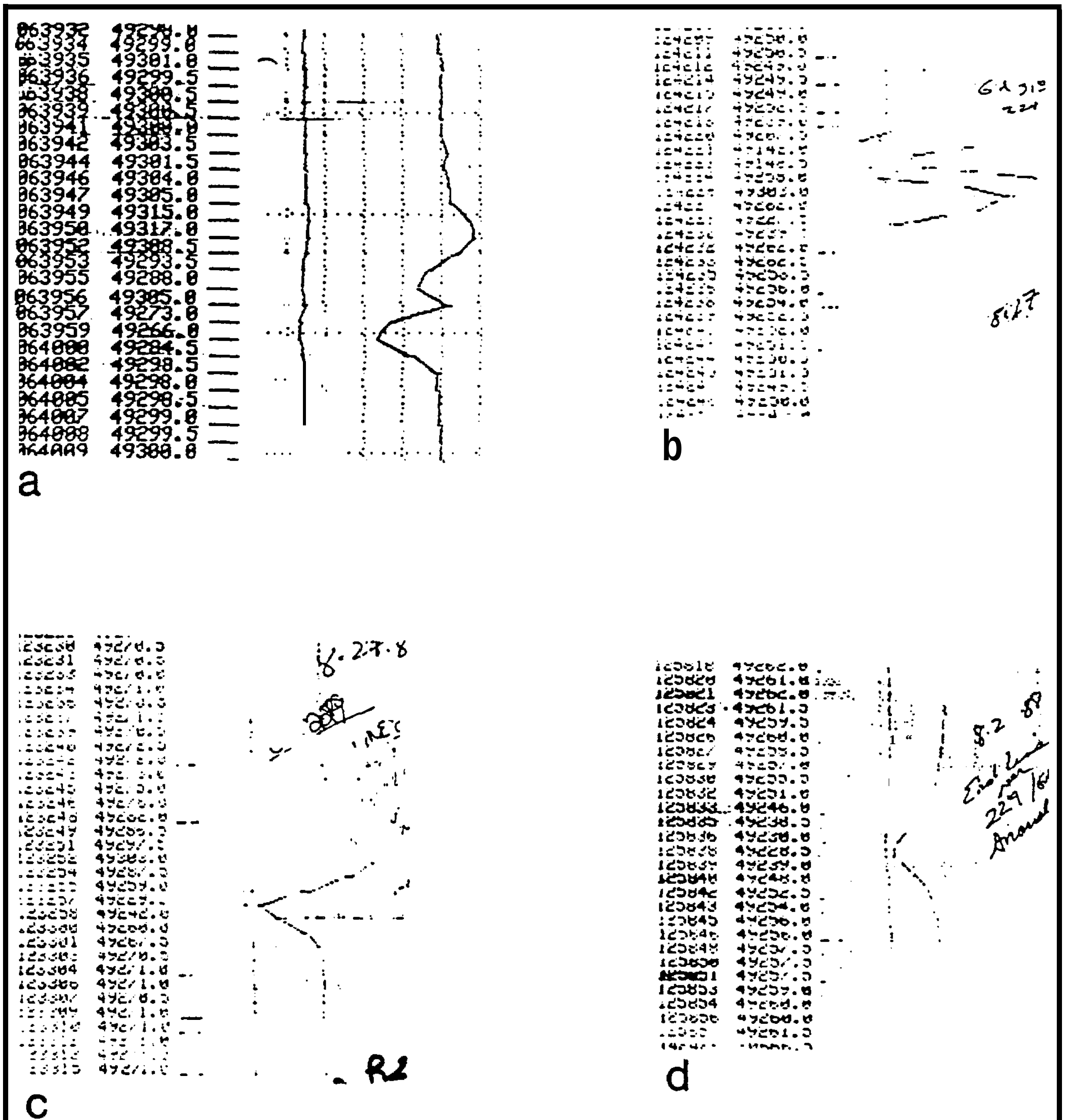

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FIGURE K-26. **Site#21 (a)** resurvey **anomaly** (b-d) anomaly detected during ground **truthing.**

K-SO

Characterization of Side. Scan Sonar Contacts and/or Magnetic Anomalies

Site #22

1. Location: 231 GA 313/ SP 15528°48'13.02" N 95°05'29.99" W

2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): magnetic anomaly

3. Instruments: EG & G Geometries G-866 proton magnetometer, EG & G 260 side scan sonar, Del Norte 542 Trisponder

4. Magnetometer Cycle Time: 1.5 sec

5. Side-scan sonar range: 75 m

6. Depth of water: 20 m (66 ft)

7. Depth of sensor: 15 m (50 ft)

8. Number of tracks: 6 total

9. Track spacing: 10 m

10, Track directions: N-S

11. Vessel speed: 2.5 m/s (5 kts)

12. Ground-truthed: no

13. Documentation: Analog magnetometer and side scan sonar data

14. Desription: The anomaly located by block resurvey (a) could not be found by relocation work. A small anomaly was detected (b,c,d). The amplitude, shape and duration differ significantly for the respective surveys. No side scan sonar contact was found and no groundtruthing was attempted. Source: unknown.

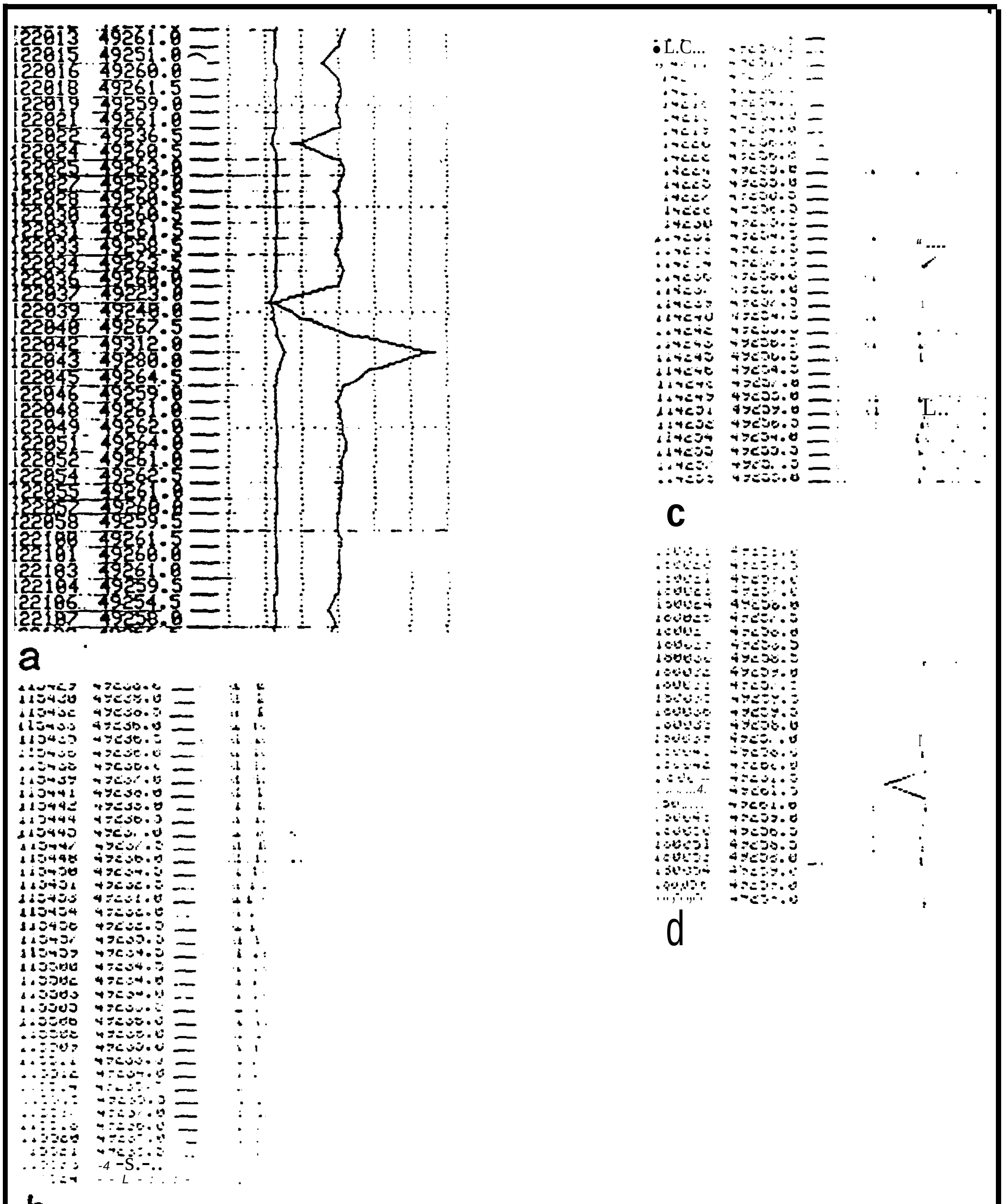

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FIGURE K-27. Site #22 **(a)** resurvey anomaly (b-d) small anomalies detected during ground **truthing.**

Characterization **of Side Scan Sonar Contacts and/or 'Magnetic Anomalies**

Site #23

1. Location: 305 GA 332/ SP 11028°47'36.34" N 95°08'38.77" W
2. Type of feature: (Magnetic Anomaly and/or Side-Scan Sonar Contact): Magnetic anomaly and side **scan sonar contact**
3. Instruments: **EG & G Geometries G-866 proton magnetometer, EG & G 260** side scan sonar, Del Norte 542 **Trisponder**
4. Magnetometer Cycle Time: 1.5 see
5. Side-scan sonar range: **75 m**
6. Depth of water: 20 m (66 **ft)**
7. Depth of sensor: 15 m (50 **ft)**
8. Number of tracks: 3 logged; 9 total
9. Track spacing: 10 **m (characterization); 50 m (survey)**
10. **Track directions: E-W, N-S**
11. **Vessel speed: 2.5 m/s (5 kts)**
12. **Ground-truthed: yes**
13. **Documentation:** Analog-digital magnetometer and navigation data. Analog **side** scan sonar data. Videotape of feature.
14. Description: The block survey located a **dipolar** anomaly on an east-west tie line. Relocation surveys refined the characterization of the anomaly **(b,c,d)** and obtained acoustical data from **fathometer** and side scan sonar **(e,f).** The divers found an 8 meter mainmast of a shrimp trawler together with attached chain, cable and debris (bucket, cans).

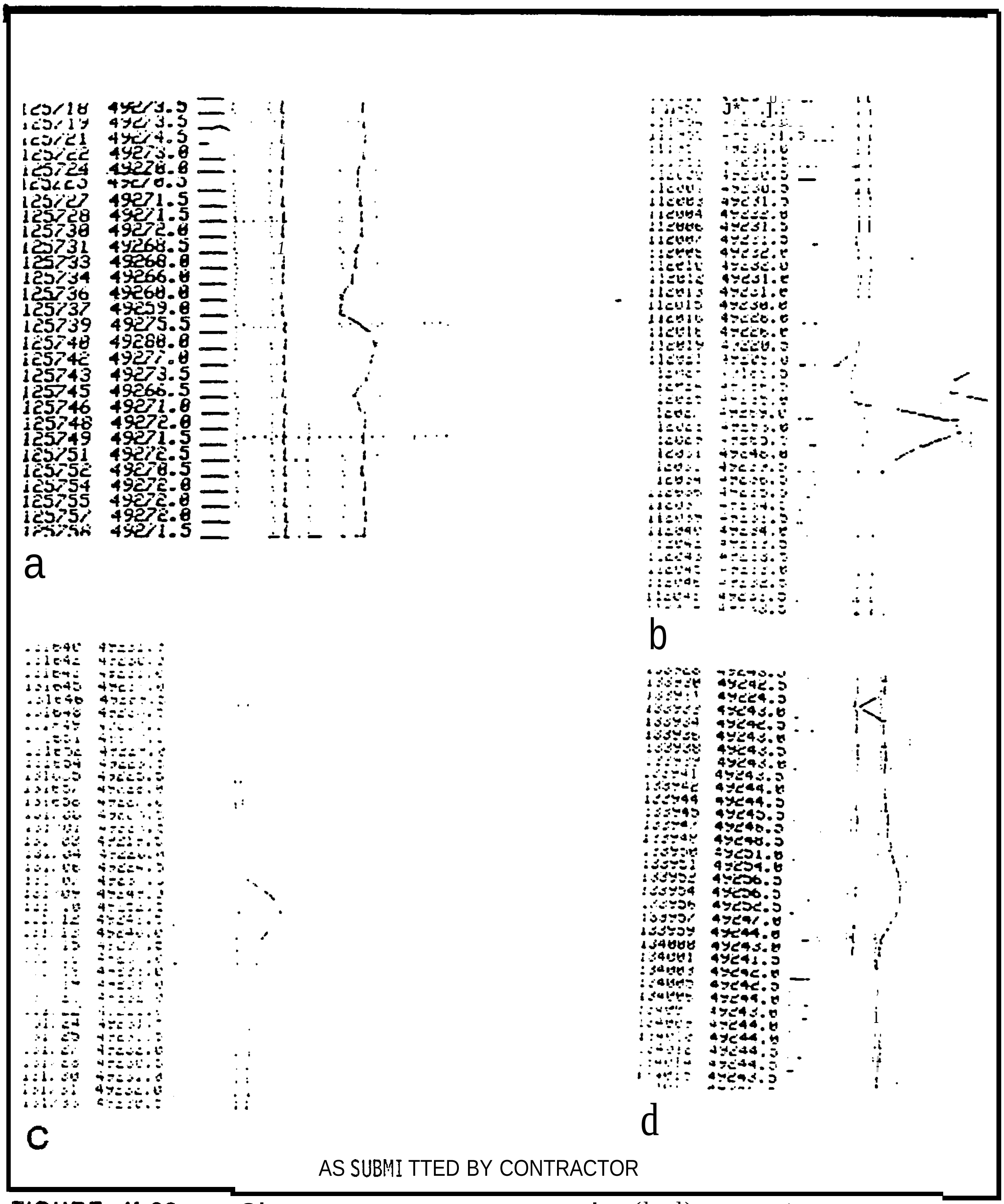
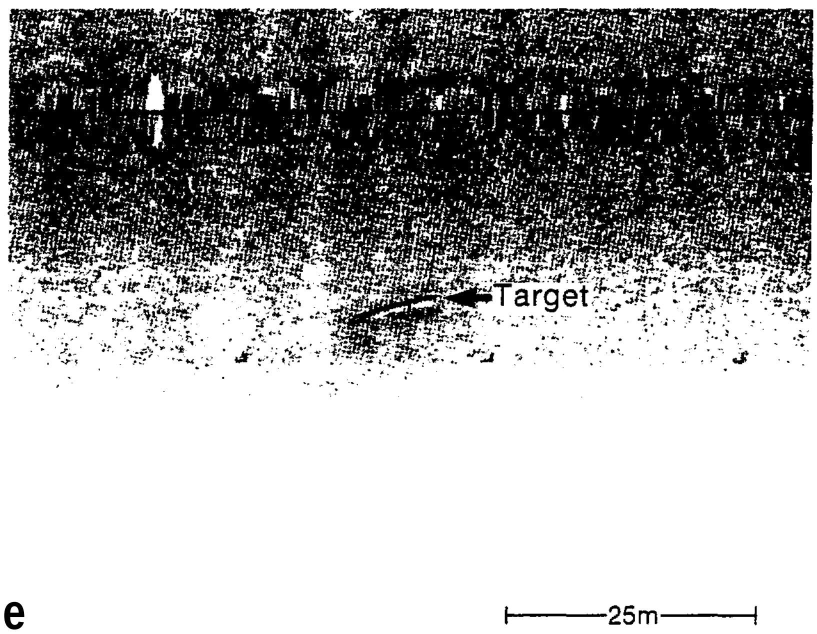


FIGURE K-28. Site #23 (a) resurvey anomaly (b-d) anomaly detected during ground truthing...



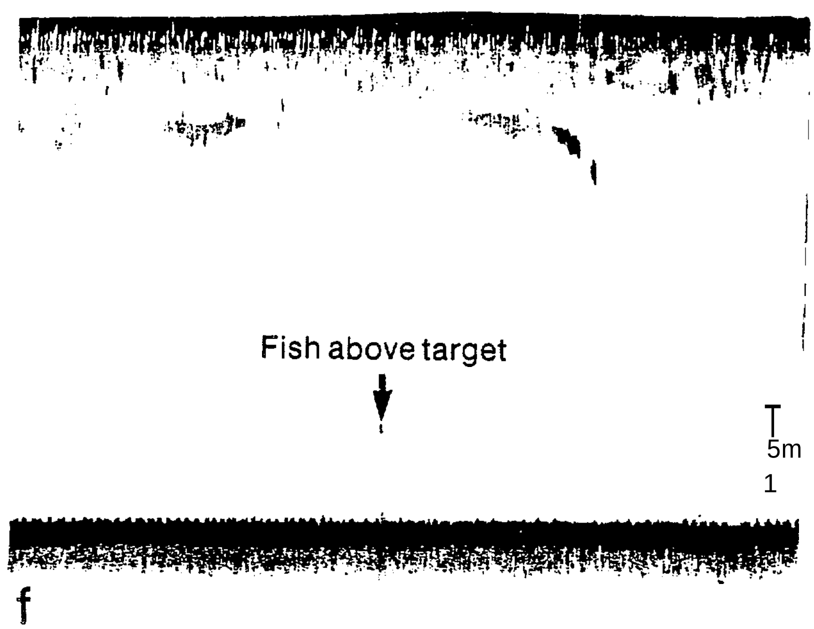


FIGURE K-29 Site #23 cont. - (e) sonograph of contact (mast); (f) fathometer record of feature (note fish).

APPENDIX L

Formulae

Table L-1.

GENERALIZED PEAK AMPLITUDE AND DEPTH-TO-SOURCE FOR VERTICALLY POLARIZED ANOMALIES **(after Von** Frese 1986).

Generalized Anomaly

MA = MM/z^n, where

MM = magnetic moment (cgs) of the anomaly source,

z = effective distance **(cm) between the** source and the **point** of observation, and

n = amplitude decay rate factor.

Depth-to-Source

z = ((-n) *(MA))/(d(MA)/d(z)), where (d(MA)/d(z)) = vertical first derivative of MA, and

n = 3 for dipoles, or 2 for monopoles and linear anomalies.

Monopolar Anomaly

$MA_m = MM/z^n = (SK^* F_e^* A_n)/(z_t^2)$, where

SK= unit volume magnetic susceptibility contrast (cgs) between the source and the country soil,

Fe = applied geomagnetic field strength,

z_t = depth to the top of the source that is assumed to be a vertical cyclinder of great relative depth extent, and

An = horizontal cross-sectional area (cm^2) of the source.

Dipolar Anomaly

$MA_d = MM/z_n = (2^* SK^* F_e^* V_s)/z_c^3)$, **where**

z_c = depth to the center of the source that is assumed to be a sphere of small relative **geometric proportions, and**

Vs = spherical source volume (cm^3)

Table **L-1**
(continued).

Linear Anomaly

$MA_1 = MM/z_n = (SK^* \ Fe^* \ A_v)/z_c^2)$, **where**

z_c = depth to the central **axis of the source that is assumed to be a horizontal** cylinder of large relative lateral extent, and

A_v = vertical cross-sectional area (cm^2) of the source.

APPENDIX M

Factor Analysis for Pattern Recognition in Anomalies

Table M-1,

Factor Analysis for Pattern: $X_1 \ldots X_4$.

Summary Information

Factor Procedure	Principal Component Analysis
Extraction Rule	75% Variance Rule
Transformation Method	Orthotran/Varimax
Number of Factors	2

Oblique Factor Scores: Columns 18- 19

Table M-2.
Correlation matrix.

	# peaks	Anomaly . . .	Anomaly . . .	Maximu...
# peaks	1			
Anomaly Area	.747	1		
Anomaly Du...	.555	.913	1	
Maximum A...	.014	.607	.819	1

Table M-3.
Partials *In* off-diagonals ● nd Squared Multiple R in diagonal.

	# peaks	Anomaly . . .	Anomaly . . .	Maximu...
# peaks	.921			
Anomaly Area	.492	.92		
Anomaly Du...	.655	.278	.968	
Maximum A...	-.879	.182	.87	.952

Table M-4.
Measures of Variable Sampling Adequacy.
Total matrix sampling adequacy: .542

# peaks	.375
Anomaly Area	.833
Anomaly Du...	.589
Maximum A...	.399

Bartlett Test of Sphericity- OF: 9 Chi Square: 64.894 P: .0001

Table M-5.
Eigenvalues and Proportion of' Original Variance.

	Magnitude	Variance Prop.
Value 1	2.901	.725
Value 2	1.029	.257

Table M-6.
Eigenvectors.

	Vector 1	Vector 2
# peaks	-.395	-.721
Anomaly Area	-.57	-.149
Anomaly Du...	-.576	.146
Maximum A...	-.433	.66

Table M-7.
Unrotated Factor Matrix.

	Factor 1	Factor 2
# peaks	.673	.732
Anomaly Area	.971	.151
Anomaly Du...	.981	-.148
Maximum A...	.737	-.67

Table M-8.
Communality Summary.

	SMC	Final Estimate
# peaks	.921	.988
Anomaly Area	.92	.965
Anomaly Du...	.968	.984
Maximum A...	.952	.992

Table M-9.
Orthogonal Transformation Solution-Varimax.

	Factor 1	Factor 2
# peaks	.027	.994
Anomaly Area	.632	.752
Anomaly Du...	.837	.532
Maximum A...	.996	-.02

Table M-1 O.
Oblique Solution Primary Pattern Matrix-Orthotran/Varimax.

	Factor 1	Factor 2
# peaks	3.422 E-4	.994
Anomaly Area	.613	.736
Anomaly Du...	.824	.511
Maximum A...	.998	-.047

Table M-1 1.
Oblique Solution Reference Structure-Orthotran/Varimax.

	Factor 1	Factor 2
# peaks	3.417 E-4	.993
Anomaly Area	.612	.735
Anomaly Du...	.822	.51
Maximum A...	.996	-.047

Table M-1 2.
Primary Intercorrelations-Orthotran/Varimax.

	Factor 1	Factor 2
Factor 1	1	
Factor 2	.053	1

Table M-13.
Variable Complex ity-Orthotran/Va rlmax.

	Orthogonal	Oblique
# peaks	1.001	1
Anomaly Area	1.943	1.937
Anomaly Du...	1.696	1.67
Maximum A...	1.001	1.004
Average	1.41	1.403

Table M-14.
Proportionate Variance Contributions.

	Orthogonal	Oblique		
	Direct	Direct	Joint	Total
Factor 1	.533	.512	.018	.53
Factor 2	E467	.449	.021	.47

Table M-1 5.
Factor **Score** Weights for Oblique Transformation **Solution-Orthotran/Va...**

	Factor 1	Factor 2
# peaks	-.311	.697
Anomaly Area	.147	.327
Anomaly Du...	.347	.104
Maximum A...	.629	-.34

Table M-1 6.
Factor Score Weights for Orthogonal Transformation Solution-Varimax.

	Factor 1	Factor 2
# peaks	-.292	.689
Anomaly Area	.156	.331
Anomaly Du...	.35	.113
Maximum A...	.619	-.324

Table M-17.

Raw data for four variables for eleven shipwreck and modern debris cases.

	PEAKS	AREA	DURATION	AMPLITUDE
1	20	5000	40	80
2	15	1000	50	500
3	13	9000	234	2659
4	46	8700	152	16
5	10	375	12	20
6	2	40	15	30
7	6	90	8	33
8	9	160	23	63
9	9	100	34	58
10	2	15	4	30
11	8	90	21	52

1) SAN ESTEBAN; 2) BLACK CLOUD; 3) WILL 0' THE WISP; 4) 1715 WRECK; 5) 125GA313; 6) 175GA313; 7) 207GA313; 8) 229GA313; 9) 305GA332; 10) 137GA332; 11) 185GA332

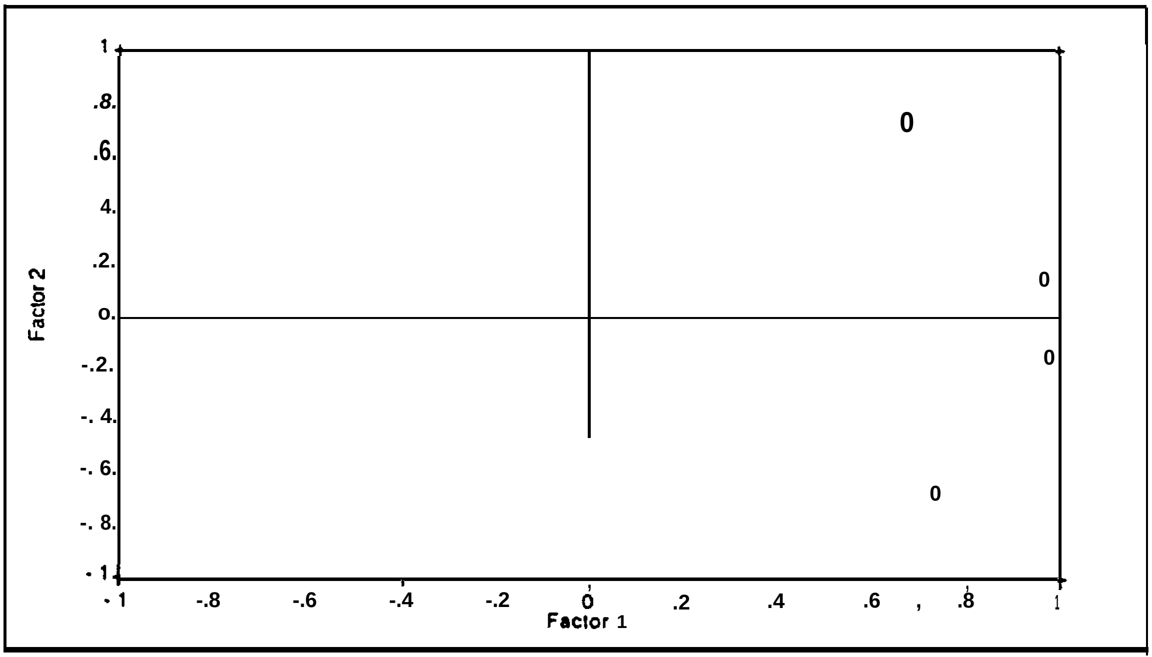


Figure M-1. Unrotated Orthogonal Plot: Factor 1 vs Factor 2.

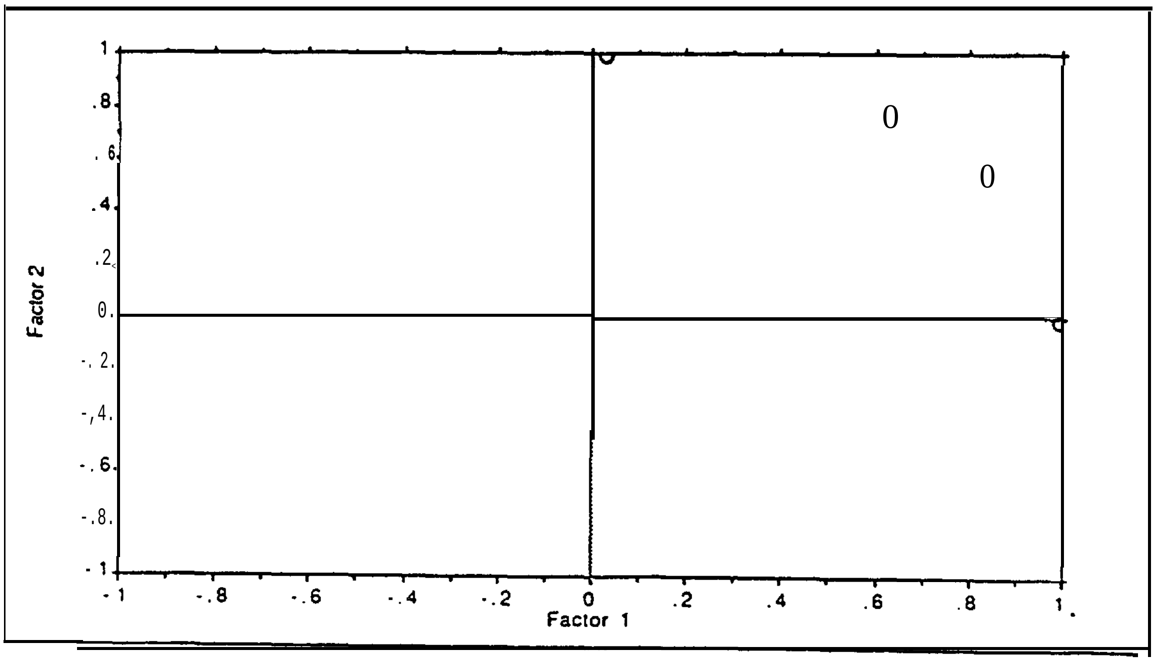


Figure M-2, Rotated Orthogonal Plot: Factor vs Factor 2.

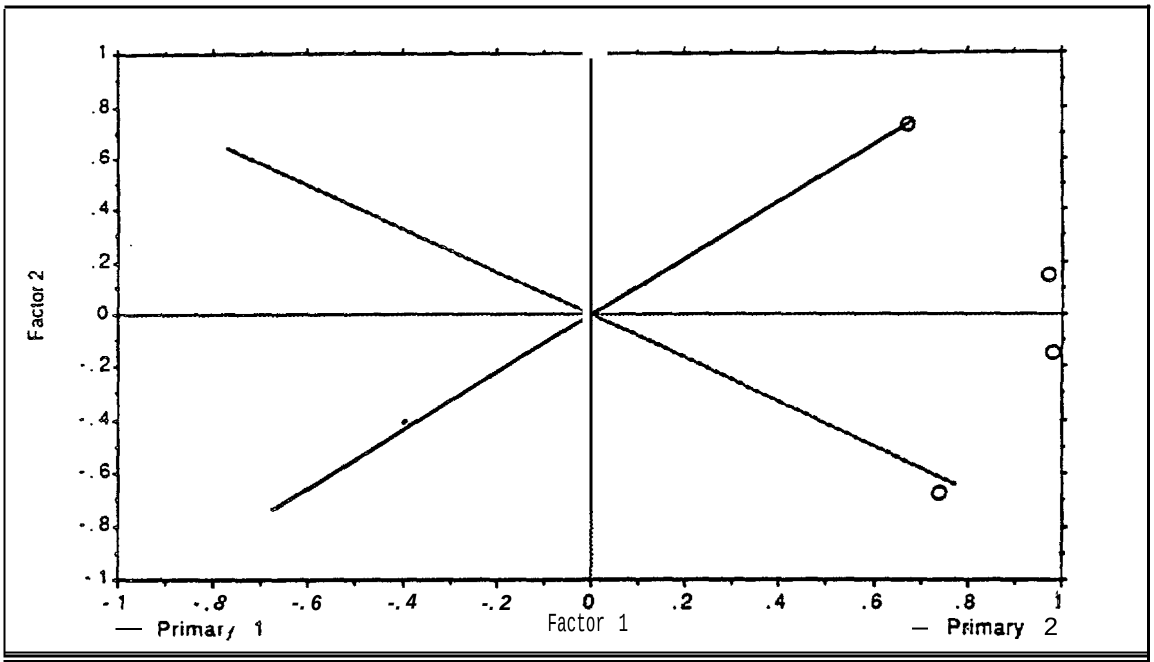


Figure M-3. Transformed Oblique Plot: Factor 1 vs Factor 2.

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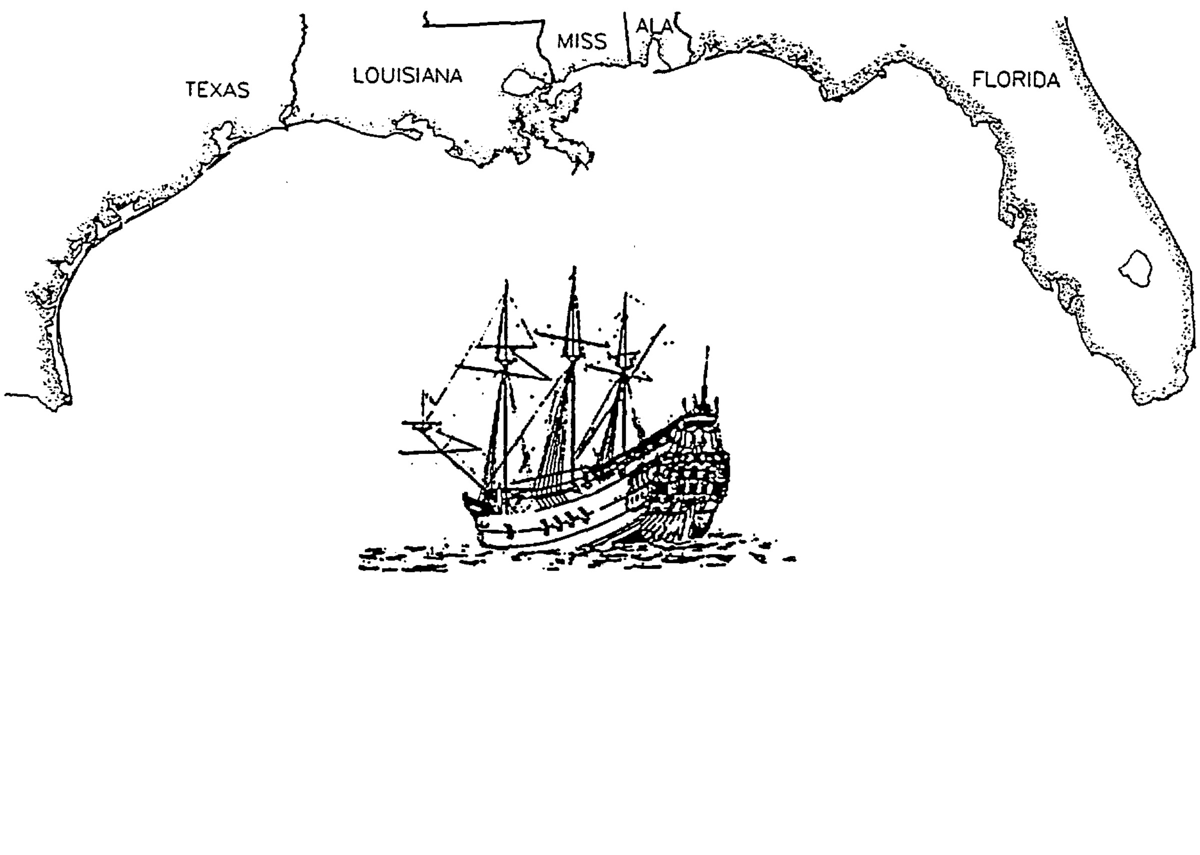
3033. OCS Study
MMS 89-0024

Historic Shipwrecks and Magnetic Anomalies of the Northern Gulf of Mexico

Reevaluation of Archaeological Resource Management Zone 1

Volume II: Technical Narrative



MMS
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS Study
MMS 89-0024

Historic Shipwrecks and Magnetic Anomalies of the Northern Gulf of Mexico

Reevaluation of Archaeological Resource Management Zone 1

Volume II: Technical Narrative

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Prepared under MMS Contract
14-12-0001-30330
by
The Texas A&M Research Foundation
Box 3578
College Station, Texas 77843

Published by

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Regional Office

New Orleans
September 1989

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CITATION

Suggested citation:

Garrison, E. G., C.P. Giammona, F.J. Kelly, A.R. Tripp, and G.A. Wolff. *Historic shipwrecks and magnetic anomalies of the northern Gulf of Mexico: reevaluation of archaeological resource management zone 7.* Volume II: technical narrative OCS Study/MMS 89-0024. U.S. Dept. of the Interior, Minerals Management. Service, Gulf of Mexico OCS Regional Office, New Orleans, La. 3 Volumes, 242 pp.

ABSTRACT

As a result of Minerals Management Service (MMS) remote sensing surveys, numerous unidentified magnetic anomalies and side-scan sonar contacts which could represent historic shipwrecks have been recorded in the Gulf of Mexico (GOM). The objectives of this study are divided into two tasks. Task I provides a collection, evaluation, and synthesis of archaeological, environmental, and geographic data to evaluate and redefine the Cultural Resource Management Zone 1 (CRMZ1) in the Gulf. The CRMZ1 is an area considered to have a high probability for the occurrence of historic shipwrecks.

Task II was designed to establish an interpretive framework that would help identify the nature of magnetic anomalies and side-scan sonar contacts within the CRMZ1. Field studies were conducted to determine the relationship between linespacing of magnetometer and side-scan surveys and the percentage of objects detected on the seafloor. These data were then analyzed to investigate whether remote sensing data gathered during a cultural resource survey could discriminate between a cultural resource and recent debris.

The results from Task I indicate: (1) an increased distribution of shipwrecks in the eastern Gulf beyond the present CRMZ1 boundary but a low preservation potential at these wreck sites, and (2) a higher potential of finding shipwrecks around historic port areas in the central and western Gulf because of higher preservation potential.

Recommendations to relocate the CRMZ1 based upon both the distribution of reported shipwreck locations and their preservation potential are made. It is proposed that the CRMZ1 be moved to within 10 km of the Gulf coast and that specific higher probability zones be delineated outside the CRMZ1 that reflect the increased frequency of wrecks in the vicinity of ports and certain hazards.

The results of Task II indicate: (1) magnetic anomalies increase in direct proportion to area surveyed, i.e. the 150 m line interval detects one-third of the anomalies compared to a 50 m line interval survey, (2) survey areas with oil and gas structures have higher numbers of magnetic anomalies than undeveloped survey areas, and (3) the present survey methods used for cultural resource surveys are not sensitive enough to differentiate between modern debris and a potential cultural resource.

Other methods can more confidently differentiate between modern debris and shipwrecks. One method forms the basis of our recommendations on Task II which suggest using 50 m lane spacing for survey areas having a high potential for shipwrecks. The recommendations in both Task I and II combine to reduce the general survey area on the Outer Continental Shelf (OCS) but increase the effectiveness of the surveys in areas that have a high probability of both shipwreck density and preservation potential.

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ACKNOWLEDGMENTS

The program manager and all of the principal investigators would like to acknowledge the assistance of the research assistants, secretaries, clerks, student technicians, student workers, laboratory technicians, draftspersons, and others who have been so instrumental in assembling this report for the Minerals Management Service.

The management staff on this project are involved in purchasing, report writing, and clerical duties which make it possible for the researchers to implement the procedures which are described in this report and their fine work is appreciated. The assistance of Mr. Mike Huddleson in coordinating project business with the Texas A&M Research Foundation, the Minerals Management Service, and outside vendors is most appreciated. Mr. William Crow coordinated many project logistics. The contribution of Ms. Susan Hulse in organizing, typing, and editing this report is most appreciated. The special help and extended efforts of Sherry Garvey, Andrea Hapeman, and Joanna Fritz are examples of how projects cannot be successful without the teamwork of wonderful staff. The work of the project field staff and the crew of the University research vessel, the R/V EXCELLENCE II, is acknowledged. Their assistance in the implementation of field sampling procedures has been very valuable and is greatly appreciated.

Acknowledgement is given to student assistants Karen Trossel, Nancy Hitchcock, Susie Riley, Robert Lightfoot, Sherry Garvey, Kyle Baden, Karen Martin, and Diane Midge for their invaluable assistance in data analysis, compilation, and transmission. Eri Weinstein participated in the 1988 field surveys of lease blocks 313 and 332 as partial fulfillment of course requirements in his graduate studies. Mr. Ron Pierce gave his usual fine effort in locating materials and equipment necessary for the successful field studies. Mr. Ben Thigpen provided expert council on survey problems, drawing on exhaustive experience in the geophysical industry.

Several vendors and their representatives provided timely service and assistance. These include Mr. Terry S. Snyder (EG & G), Mr. John Fett (John D. Fett Instruments), Mr. Alistair Helme (Harvey-Lynch, Inc.), Mr. Larry Stephenson (Harry-Lynch, Inc.), Mr. Chuck Edgington (Del Norte Technology, Inc.), Mr. Andy Bogle (STARFIX), Mr. Jack Rhodes (STARFIX), Mr. Dick Smith (STARFIX), Mr. Jeff Raspberry (STARFIX), and particularly Mr. Max Huff (STARFIX). The tow-depth sensor used during the field studies was graciously provided by Teledyne Exploration, Inc. through the offices of Mr. Carl Bergland. EG&G Geometries gave its usual fine product support and is thanked for updating our G-866 magnetometer.

Our thanks go to Mr. James Baker and Mr. James Orr for preparing the excellent DISSPLA graphics included in this report. The staff of the Engineering Computer Services (ECS) of the Engineering Program, Texas A&M University, provided technical and advisory assistance over the course of the study. In particular, Mr. J. Robert Shaeffer (now with Boeing Computing Services), Mr. Jeff Cox (ECS) and the director of ECS, Dr. Donald Maxwell, are thanked. Dr. Maxwell authorized the acquisition of the NUMONICS digitizer and DEC 220/240 terminals so important to the manipulation and presentation of the large digital databases used in this study. The study benefited from his complete support as Interim Department Head, Civil Engineering Department, Texas A&M University.

Dr. Robert Bruner of the Geotechnical Area, Civil Engineering Department, erected the geodetic controls used in the resurvey of lease blocks GA 313 and GA 332. Dr. Bruner and his son, Bill, cheerfully rode boats and helicopters to erect the offshore positions to the highest degree of accuracy. The control points were erected on properties of Santa Fe Minerals and Exploration Co., Lorac, a division of John E. Chance Associates, and the United States Coast Guard (Surfside, Texas). Each of these organizations is thanked for this courtesy.

We gratefully recognize ARMS, Inc. whose personnel, Mr. Nathan Gauthier (President), Mr. Randy Ducote, and Mr. Robert Simon were always able to accommodate our requests.

During the summer field studies several divers volunteered their assistance. Most were students of Texas A&M University and include: Mike Halpin, Marianne Franklin, Kenan Heideke, Alan Haubaker, Jim Jobling and Kathleen McLaughlin-Neyland.

Excellent examples of graphic displays of magnetic anomalies were provided by Mr. Robert Gearhart and Mr. Clell Bond of Espey-Huston and Associates, Inc., and by Mr. Rick Anuskiewicz. A photo of the machinery of the WILL O'THE WISP was generously loaned by Mr. Larry R. Martin.

Finally, we wish to thank those members of the Minerals Management Service we worked with most closely over the course of the study. They are: Dr. Norman Froomer, Ms. Melanie Stright, Dr. Richard Defenbaugh and Dr. Rick Anuskiewicz. Their counsel and assistance greatly enhanced the conduct and results of this study.

*Task I An Evaluation of **Cultural** Resource **Management** Zone 1*

1.0 INTRODUCTION

For more than 11 years, the Federal Government has required oil and gas lessees to conduct remote sensing surveys for the detection of significant historic and prehistoric archaeological resources prior to development of their leases on the Outer Continental Shelf (OCS). The authority for this requirement is based primarily on the National Historic Preservation Act of 1966, as amended, which states in effect that any Federal Agency, prior to approving federally permitted or federally funded undertakings, must take into consideration the effect of that undertaking on any National Register or National Register eligible property. Also stated in Section 110 of this legislation and in Executive Order 111593 is that an effort must be made to locate such properties prior to development of an area. The OCS Lands Act Amendments of 1978 specifically states in Section 206(g)(3) that "such exploration (oil and gas) will not . . . disturb any site, structure, or object of historical or archaeological significance." The National Environmental Policy Act of 1969, as amended, states in Section 101(b)(4) that the Federal Government has a continuing responsibility to ". . . preserve important historic, cultural, and natural aspects of our national heritage . . ."

In 1977, a baseline study, *Cultural Resources Evacuation of the Northern Gulf of Mexico Continents/ Shelf, 3* vols., Coastal Environments, Inc., was conducted in order to better determine where significant properties may occur in the Gulf of Mexico (GOM). This study generated models for predicting the locations of historic and prehistoric archaeological sites on the OCS. (These reports are available from the National Technical Information Service (NTIS) with the following order numbers: *Vol. /, Prehistoric Cultural Resource Potential,* PB-276773/AS; *Vol. II, Historical Cultural Resources,* PB-276774/AS; and *Vol. Ill, Maps,* PB-286-874/AS.) *The Minerals Management Service (MMS) Manual for Archaeological Resource Protection* requires that these archaeological baseline studies, which are the basis for MMS decisions on where to invoke the archaeological survey requirement, be updated as new data become available.

As a result of MMS required lease block remote sensing surveys, numerous unidentified magnetic anomalies and side-scan sonar contacts which could represent historic shipwrecks have been recorded in the GOM. These surveys also recorded numerous examples of relict late Wisconsin landforms (fluvial channels with evidence of terraces and point bars, bays, lagoons, barrier islands, natural levee ridges, salt diapirs, and sinkholes) where there is a high probability for associated prehistoric sites.

Avoidance or further investigation of archaeologically sensitive areas is usually required prior to approval of lease permits; however, because industry has generally chosen avoidance rather than further investigation of these areas, little data have been collected which would help in building an interpretive framework for the evaluation of unidentified magnetic anomalies and side-scan sonar contacts, or in evaluating the predictive model for prehistoric site occurrence.

1.1 Objectives

The objectives of this study are:

a To reevaluate and make recommendations to change, if necessary, the location of Cultural Resource Management Zone 1 in the GOM.

b. To determine the relationship between linespacing of magnetometer readings and side-scan sonar and the detection of objects at or below the seafloor,

c. To investigate whether remote sensing data gathered during a cultural resource survey in the GOM can be analyzed to discriminate between a cultural resource and recent debris.

1.2 Scope of Work

This study was divided into two major tasks: Task 1, Evaluation of Cultural Resource Management Zone t and Task II, Establishing an interpretive framework to characterize unidentified magnetic anomalies and side-scan sonar contacts.

Task 1. The evaluation of cultural resource management zone 1 provided for collection, evaluation, and synthesis of archaeological, environmental, and geographic data to evaluate and redefine MMS's Cultural Resource Management Zone 1, if appropriate. Cultural Resource Management Zone 1 is an area considered to have a high probability for the occurrence of historic shipwrecks. Industry is required to perform magnetometer and side-scan sonar surveys in Zone 1 prior to commencing exploration, development, or pipeline projects. The boundary of Cultural Resource Management Zone 1 is depicted on Environmental Impact Statement Visual No. 11, Gulf of Mexico, 1983 (Figure 11-1). The Zone 1 boundary depicted in the CEI study, Volume 3 is identical to that in Visual No, 11. This phase of the study required the following two efforts: (1) information collection; and (2) information analysis and synthesis.

The following data sources were analyzed as part of Task I and synthesized into this report:

a *The Cultural Resources Baseline Study (of the Northern Gulf of Mexico Continental She/f,* Volumes 1, II, and III) by CEI, 1977.

b. Historic maps and other literature sources--These were reviewed to establish the locations of historic ports, harbors, and other navigable waters where shipwrecks are likely to be concentrated.

c. Historic shipping routes as shown by CEI (1977)--The possible influence of factors such as mean wind and current directions on modifying actual sailing routes were evaluated.

d. Information on historic hurricane paths--in combination with literature and archival information on ships lost during hurricanes, this information was used to determine the relative importance of hurricanes on historic ship losses. Available information on the intensities of different hurricanes is also included. The goal of this work was to determine if hurricane paths could be used to predict shipwreck concentrations for various time periods.

e. The locations of shipwrecks discovered since the completion of the CEI baseline study--These shipwrecks were added to CEI's list. The locations of known shipwrecks, why the locations are known, and how these locations can be used to predict the location of other historic shipwrecks are discussed.

f. Available information on the historic locations of shoals, reefs, sand bars, and barrier islands--This information was evaluated as a predictive factor in shipwreck location.

g. Factors such as bottom sediment types, depth of unconsolidated sediments and GOM wave and current energy zones--The effect of these factors on the state of preservation and integrity of shipwreck sites was evaluated.

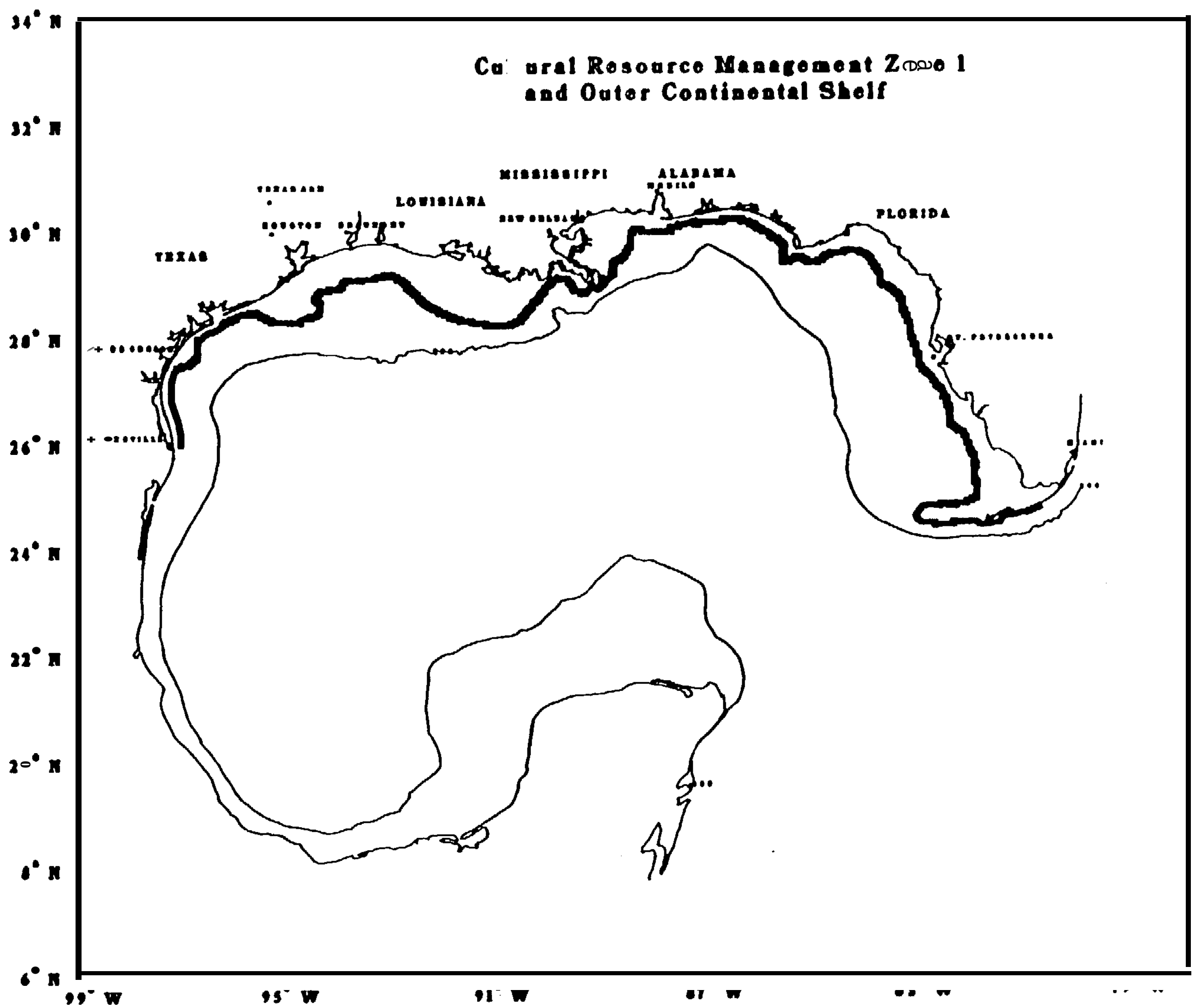

FIGURE II-1. Cultural Resources Management Zone I and the Outer Continental Shelf, Gulf of Mexico.

1.3 Previous Studies

The CEI study considered the occurrence of shipwrecks and related artifacts as the basis for determining the probability of the existence of cultural resources. The CEI researchers confined their study -area northward of 26 degrees latitude (CEI 1977; Figure II-2). Their study used a methodology based on:

a spatial bounding north of 26 degrees latitude;
b. temporal bounding of four periods ranging from 1500-1945;
c. collection of shipwreck data within (a) and (b);
d. evaluation of shipwreck locations, their frequency, and preservation factors (sediments, energy zones, etc.);
e. evaluation of factors causally related to the observed shipwreck frequency, both spatially and temporally; and
f. evaluation of discovery or exploration techniques for locating shipwrecks.

Their study relied on library documentary sources for the bulk of the data utilized in the analyses and interpretations. CEI's study included the prehistoric millennia for the northern Gulf of Mexico as well (Vol. I). This aspect is outside our consideration so this review focuses only on the last two volumes of that study.

Since the CEI study, similar studies have been conducted using similar document-based methods (Bourque 1979; Science Applications, Inc. (1981). These later studies are multi-volume evaluations of cultural resources of the OCS from the Bay of Fundy to Cape Hatteras (Bourque 1979) and Cape Hatteras to Key West (SAI 1981). The methodology used in this study considers all the factors involved in the occurrence and preservation of historic cultural resources on the OCS.

Every study concentrates on specific factors over others. This is done because of a) investigator expertise, b) specific hypotheses to be evaluated, or c) available data. The CEI study is biased to the prehistoric archaeology of the northern Gulf of Mexico. In particular, it develops an explanatory model for the occurrence of drowned sites of the OCS. CEI recently published the results of the study which focuses on the occurrence and potential preservation of prehistoric archaeological sites on the OCS (Pearson, et. al. 1986).

The Bay of Fundy Cape Hatteras study (Bourque 1979) develops a predictive model based on historic patterns of shipping to evaluate shipwreck locations. The Cape Hatteras-Key West study (SAI 1981) applied an inductive modeling approach to shipwreck distribution. These studies attempted to define management zones for both prehistoric and historic cultural resources on the OCS. Each must be viewed as approximations of the cultural resources located on the vast coastal plains that now form the drowned shelf.

CEI (1977) and other initial surveys are attempts to indirectly define archaeological phenomena over broad areas of the continental margin. All authors involved in these studies have pointed out the general nature of the research and the inadequacy of the available databases. These attempts have conceptual merit but little predictive or hindcast power in the delineation of the archaeology of the OCS. They are “educated guesses” made after consideration of the available data. Smith (1978) presents a comprehensive treatment of the data relating to New World shipwrecks. The present study cannot redress this lack of primary, direct archaeological observations which are necessary to construct a realistic picture of historic cultural resources on the northern Gulf OCS.

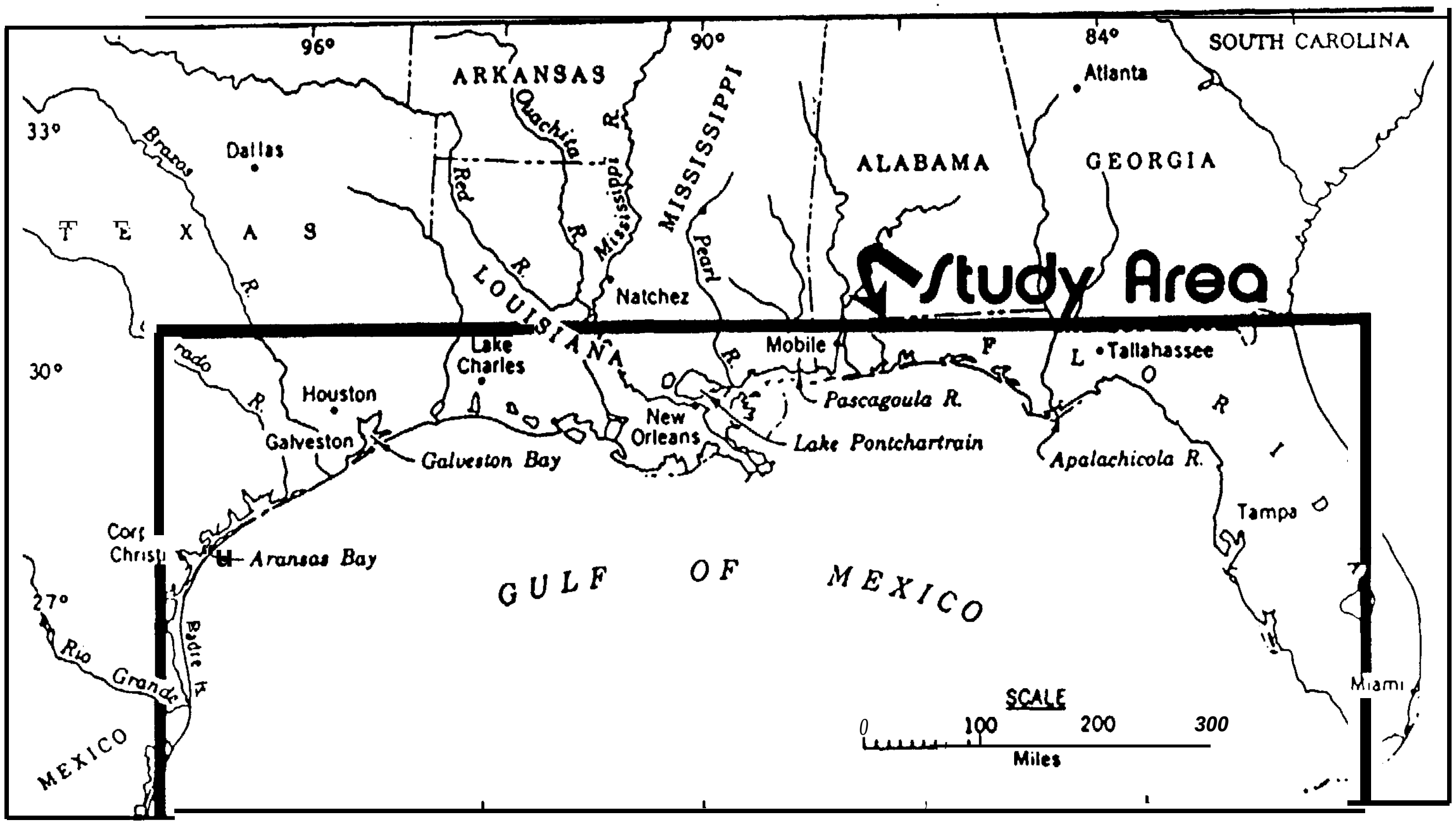

FIGURE II-2. Study area, CEI 1977.

With these caveats in mind, this report updates and expands CEI's original data to consider historical, archaeological, geological and geophysical research that has been done since 1977. Historical and archaeological syntheses since 1977 include the previously mentioned Padre Island shipwreck study (Arnold and Weddle 1979) as well as Weddle's recent excellent works, *Spanish Sea* (1985) and *La Salle, the Mississippi, and the Gulf* (1987). Secondary sources such as Surrey's study of commerce of French Louisiana (1916) and Chaunu and Chaunu's (1955) monumental study of Spanish commerce from 1504-1650 have been examined. By building on such scholarly works and incorporating CEI's framework into our study, some new insights are gained into the causes and distribution of shipwrecks on the northern Gulf Continental Shelf.

The few archaeological studies on the OCS include the excellent work on the 1554 ship wrecks off Texas (Weddle and Arnold 1979) and the EL NUEVO CONSTANTE (Pearson, et. al. 1981) as principal examples. Other reports, published or not, are of variable quality and include Hole's (1974) report on the blockade runner ARCADIA, Arnold and Hudson's (1981) paper on the USS HATTERAS, and Garrison's (1986) ITM proceedings report on the blockade runner, WILL O'THE WISP, and reports by treasure hunters such as the recent flamboyant discovery of the ATOCHA (Mathewson 1986).

Advantage was taken of a source unavailable to CEI - computer-based data files. Some of these files are *The Hangs and Obstructions File* by the Hydrographic Office (HO), *The Automated Wreck Obstruction Information Service file* (AWOIS) of the National Ocean Survey, *The Historic Shipwreck File of Texas Antiquities Committee* (TAC) and *The Florida Shipwreck File of the Division of Archives and History, State of Florida.* While relying on secondary materials as their main sources, these compilations represent professional efforts at systemizing shipwreck information by use of the retrieval speed and storage capability of the computer.

The shipwreck data in this study were organized in a similar manner to that of the AWOIS file. The data from primary and secondary materials collected at the various archives were merged and a master file of historic shipwrecks of the northern Gulf of Mexico was created. This file, with over 4,000 entries, represents the largest such data base for the Gulf.

The data used in this study are plotted as accurately as possible. The location of historic shipwrecks and the resulting distributions as a function of historic and natural factors are examined. Covariance between specific factors and shipwreck patterns was then examined for causality versus random occurrence.

The methods and sources used for data collection are detailed in the following sections.

2.0 METHODS - GENERAL

The CMRZ1 is defined as a high probability zone for the occurrence of historic shipwrecks. The observed distribution for historic shipwrecks is a product of historical and natural factors. Historic factors include cultural, economic, and technological change and natural phenomena include storms, currents, winds, shoals and reefs.

This study evaluates some of these factors over a period ranging from the 16th to the 20th centuries. Such a study is termed diachronic since it examines relationships in interacting variables (factors) over time. It is assumed that these factors differentially influenced the location and density of shipwrecks in the northern Gulf of Mexico. Numerical methods are utilized where quantification in variables allows such analyses.

Again, the CEI study was our point of departure. New research expanded state files on shipwrecks, in particular, those of Florida and Texas (Arnold 1980). Newly acquired microtexts, such as the Colonial Archive records for the French administration of the Louisiana territory, were located at Tulane University. Newly published cultural resources studies were used for historic Gulf ports such as Mobile, Alabama; Pascagoula, Mississippi; Biloxi, Mississippi; Pensacola, Florida; Gulfport, Mississippi; and Brownsville, Texas.

Updated holdings were found at the P.K. Younge Library at the University of Florida, Mariners Museum in Newport News, Virginia, the Howard Tilton Library at Tulane University and the DeZavala and University of Texas Libraries in Austin, Texas. The Sterling C. Evans Library of Texas A&M University has become a repository of secondary sources owing in large part to its affiliation with the Institute of Nautical Archaeology (INA). New guides to the extensive holdings of major Spanish archives such as Archivo General de Ias Indies (AGI), Seville and Archivo General de la Nation (AGN), Mexico City have been published or otherwise made accessible for use in this study.

2.1 Chronological Considerations

In order to better isolate and evaluate data relating to Gulf shipwrecks it is necessary to impose a chronological order on the data that approximates major historic or technological periods for that region. CEI defined four periods: (1) 1519-1699; (2) 1700-1819; (3) 1820-1 899; and (4) 1900-1945. Our major periods are:

A. New Spain Period, 1500-1699 (16th/17th centuries);
B. Colonial Period, 1700-1803 (1 8th century);
C. American Period, 1803-1865 (19th century, early);
D. Victorian Period, 1866-1899 (19th century, late); and
E. 20th Century, 1900-present.

“Period” is used in the sense of a time interval whose beginning and ending dates are well established (Willey and Phillips 1958). Correlation of the earlier CEI classification with this study can be made because the CEI time periods are the same as ours for consistency.

Period A, the New Spain Period, is that of the early explorers such as Ponce de Leon and Hernando Cortes. It is highlighted by the exploration, conquest and exploitation of New Spain which led to further Spanish expansion into the northern Gulf region. This period also includes the French entry into the northern Gulf. The terminal date reflects the establishment of the French as a major colonial presence (Wood 1979, Weddle 1985, Webb 1952, Sauer 1968 and 1980, Bolton 1915, Dunn 1971).

Spain, France and Britain played significant roles in the northern Gulf area during Period B, the Colonial Period (Dunn 1971, Rea and Service 1982, Charlevoix 1763, 1766). This period is further divided into the effective end of French involvement in the northern Gulf (1700-1763), the establishment of British control of Louisiana and West Florida asa result of victory in **the Seven Years War (1763-1781) and the last period of Spanish control beginning with Galvez's capture of Pensacola (1781-1803).**

Period C, the American Period, is the period from the cession of Louisiana to the United States by Napoleon up to the fall of the Confederate States of America and the end of the American Civil War. It is the beginning of American control of the northern Gulf and its increased shipping activities. New ports, such as Galveston (1821), Freeport (1830), Brownsville (1849), Cedar Key (1866), Key West (1828), and Tampa (1855), make the northern Gulf an American sea after three centuries of Spanish domination.

Period D, the Victorian Period, reflected post-war and later increased maritime activity. The war period of 1861-1865 resulted in few shipwrecks as a result of direct action by either the Confederacy or the Union. Confederate Blockade runners such as the ACADIA and the WILL O' THE WISP were run to ground by Union blockades and the U.S.S. HATTERAS ran afoul of the famous Confederate cruiser, ALABAMA, becoming perhaps the most notable shipwreck of this era on the OCS. Ports continued to grow and thrive along the Gulf from Texas to Key West.

Period E, the 20th Century, covers the period of transition from an agrarian based economy to today's emphasis on manufacturing and petrochemicals. Additional shipwrecks occurred in the northern Gulf during World War II as German submarines or U-Boats attacked commercial shipping. Two of these submarines, the U-157 and the U-166, rest in the northern Gulf (Röhwer 1983) (Appendix A).

These periods were used to organize the shipwreck data for discussion purposes. Our distribution maps combine various periods so shipwreck patterns and trends can be plotted in the Gulf over time.

2.2 **Geographical** Considerations

The original CEI study encompassed an area of the northern Gulf of Mexico above 24"N and west of 80°30'W. The same area was used in our study but we extended the east boundary to 80°W.

2.2.1 *The Determination of Latitude-Longitude Points of Shipwrecks*

The methods used to assign coordinates to the data are discussed in the next two sections. The sources of information for this report were in various forms including manuscript listings, magnetic tapes, computer discs, and literature. The formats of these sources also varied. A modified AWOIS format has been used in the final database. This format includes ship name, approximate date of loss, abbreviated source name, and latitude and longitude of the approximate location (Appendices G and H). Other files are available which include the descriptive location of the ship loss. This database, which contains approximately 4,000 entries, is the largest computerized shipwreck file ever assembled for the Gulf of Mexico. Computerization allows the file to be continually updated as well as manipulated for different uses.

Some of the sources did not provide exact latitudes and longitudes of the ship wrecks; however, descriptive locations were provided.[1] Latitudes and longitudes for the shipwrecks were obtained by using these descriptions, large scale charts, and a Numonics 2400 digitizer. Descriptions such as "off the coast of ---" were assumed to be at the site in question. In addition, those points described as "X miles off the coast of ---" were assumed

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[1] An early example is the Spanish reference to Matacumbe. This name was applied to the entire keys area with the exception of the Maraquesas (Smith 1976).

to be perpendicular from that coastline. A list detailing assumptions for each site is available as an appendix (Appendices G-1) to this report.

The data were verified by rechecking a random sample using the digitizer. When the exact latitude and longitude were provided, duplicate listings of the wrecks from other sources provided another means of verification.

The sources were examined to determine the most reliable one. Primary sources were considered more reliable than secondary ones. When duplicate ship entries occurred, all but the most reliable were deleted. In instances where the name and date were identical but the location varied within one-tenth of a decimal degree, the information from the most reliable source was retained.

2.2.2 *Accuracy, Precision, and Assigned Shipwreck Positions*

The accuracy of shipwreck positions assigned in this study is primarily a function of: (1) geographic coordinates given for the shipwreck and (2) level of precision in the particular analysis. The first factor, geographic coordinates given to the shipwreck, is dependent on the reporting period of the loss. Geographic coordinates were infrequently used to report early shipwrecks. Before the 20th century and up to the present day, shipwrecks were located utilizing some shore landmark as a reference. This is far less common today where electronic navigation is the rule.

The second factor, level of precision, is directly related to that precision required of the particular spatial analysis being used in this study. For instance, the highest locational precision used in this study is the lease block. The accuracy of the shipwreck positions is 0.16 for an assigned lease block whose original report gave no quantitative position.[2] However, the spatial analyses of this study did not require high precision for shipwrecks in lease blocks, and we typically used larger quadrats that increased the chance for the position reported or assigned to be within the quadrat.

While we carefully and systematically assigned the accuracy of shipwreck positions to our charts, we were concerned with overall distribution patterns that required less accurate relative position locations (Appendix H briefly describes the methods used to determine shipwreck positions on distribution charts in this report). For instance, travel routes to the Carrera de las Indies of the 16th to 18th centuries could vary over 2 degrees in position (120 miles) depending on the trade winds and currents. To correlate a scatter of shipwrecks with such a broad traffic pattern does not require a locational precision much smaller than the variability in that of the independent factor (e.g. traffic routes).

The same is true for hurricane paths. Their occurrence within the Gulf of Mexico reflects statistical uncertainty. Areas of greater or lesser probability for these storms along the northern coast produce large areal sectors. To correlate a pattern or density of shipwrecks of a similar scale does not require a positional accuracy that is below that seen for the hurricanes themselves.

AWOIS or TAC databases give more precise accuracies. AWOIS, for instance, gives a circle of error for the reported position of one mile, three miles, or greater than three miles. TAC utilizes a margin of error based on a reasonable probability that a shipwreck will be within a six lease-block cluster of the given position.

2.3 Data Sources

Hanable (1983) identified four major sources of shipwreck information: (1) databanks; (2) documents; (3) directories; and (4) descriptions. To this classification we should add (5)

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[2] Probability based on the possible shipwreck location being within an area of six lease blocks or 54 square miles. This follows techniques used by the Texas Antiquities Committee and Borque (1 979),

other secondary literary sources. Data banks are organized, comprehensive collections of detailed data which have been stored and are accessible for rapid retrieval. Directories are lists of the names of vessels and usually include dates and locations of casualties. Documents are unpublished materials that provide substantive data about shipwrecks. Descriptions are acccounts of individual shipwrecks. Secondary literary sources are described below.

2.3.1 *Shipwreck Data Banks*

Four major shipwreck data banks exist at the federal and state level for shipwrecks in the northern Gulf of Mexico. These files are:

a. the *Texas Antiquities Committee Shipwreck File* (TAC), Austin, Texas;
b. the *Shipwreck File*, the Bureau of Archaeological Research, Tallahassee, Florida (BAR);
c. the *Automated Wreck and Obstruction Information Service* file (AWOIS), National Ocean Service, Rockville, Maryland; and
d. the *Hangs and Obstructions file* (HO), Hydrographic Office.

The TAC shipwreck file is a Dbase, MS-DOS type file with over 1800 entries. Most of these entries are from secondary sources but many have been added based on data obtained from the TACS Historic Map Project conducted in 1979[3]. File categories include: name, year lost, position (descriptive, geographic, latitude/longitude), block number (refers to oil and gas lease block number, Texas state lands), and vessel type.

The Florida shipwreck file has been created by the Bureau of Archaeological Research, Division of Historical Resources. It is an MS-DOS file existing in Dbase II and III formats, For the Gulf portion of the file there are well over 700 entries.[4] File categories include: wreck number; tonnage; name; year built; vessel number; where built; nationality; date lost; home port; nature; vessel type; position (descriptive and geographic); notes; and comments.

Another data bank for shipwreck research is the Automated Wreck and Obstruction Information Service file (AWOIS), maintained by the National Oceanic and Atmospheric Administration. Developed within the past five years, this data bank is an ASCII file containing 3,100 records of items the National Ocean Survey considers obstructions to navigation. Individual files for each vessel or obstruction entered in this data bank include four types of records. These are: name records, history records, description records and survey requirement records. Name records have, among other data, vessel, name registry numbers, and latitudes and longitudes of location. History records have information relative to the original and revised presentations of information about the wreck or obstruction on nautical charts. Description records have a reference source (by numerical designation) and specific descriptive information such as vessel dimensions, age, construction type, date sunk and other miscellaneous information which may include last recorded owner, present wreck condition, if the wreck is a local diving or fishing attraction, etc.

The Hydrographic Office's Hangs and Obstruction (HO) file is another easily obtained data source for shipwreck information. It is a recently developed ASCII file like AWOIS. Specific categories in the file are: wreck number; position evaluation; name; source of position; nationality (two letter code); position (latitude/longitude); type of wreck; depth over wreck; flag of sinking agent; date of sinking agent; type of sinking agent; and date of information.

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[3] J. Barto Arnold 1987, personal communication.
[4] James Miller 1987, personal communication.

Each of these databases may duplicate information within another database. [n the case of the HO and AWOIS files, this duplication allows a cross check on the reports for each wreck. The TAC and Florida files have evolved as strictly shipwreck databases. They extend further into the historic record, but rely on secondary sources for most of their information. Specific advantages and disadvantages of the four databases are listed in Table 11-1.

2.3.2 *Documents*

Documents, as defined above, are unpublished materials that provide substantive data about shipwrecks. Sources for shipwreck information consist of newspaper or magazine articles, maritime historical accounts and official records. Official records are the most reliable source but are varied in information content. Maritime countries such as Spain, France, and Britain maintained shipping lists (records of returns, etc.) and logs for commercial and naval craft. Such documents, kept in archives throughout the world, vary in their systematic recording and filing practices. The ability to relocate a wreck site was not a criterion in most accounts of maritime disasters until the 20th century,

2.3.2.a Record Groups, Federal

Record groups (RG) are in the National Archives and in regional federal archives and record centers. The following groups contain information pertinent to shipwrecks in the Gulf.

The Records of the Steamboat Inspection Service (RG41), established in 1854, continue into the 20th century. RG26, Records of US. Coast Guard and RG35, Records of U.S. Custom Service are government documents of wrecks after 1874. In that year Congress required masters or owners of American vessels to report any casualty to the vessel to the Collector of Customs at the port at which the vessel was documented. A casualty could be an incident involving loss of life, serious injury to any person, material loss of property, or damage to a vessel affecting seaworthiness. The Collector of Customs forwarded one copy of a casualty report to the General Superintendent of the United States Life-Saving Service and kept one copy, usually copied into volumes containing blank wreck reports. The volumes are among the Records of the U.S. Customs Service (Record Group 36). Customs wreck reports from 1913 to 1939 are available on National Archives Microfile T925. National Archives Microfile T926 is an “Index to US. Coast Guard Casualty and Wreck Reports.” Also among Coast Guard records are bound volumes of abstracts of wreck reports received from Collectors of Customs from 1874 to 1975 and original reports from 1908 to 1913 (RG26).

Table II-1.

AUTOMATED SHIPWRECK DATA BASES -SOME ADVANTAGES AND DISADVANTAGES.

AWOIS

Advantages:
1. automated
2. continually updated
3. good location with an evaluation of accuracy
4. record of wreck condition
5. ground-truth data

Disadvantages:
1. limited to the 20th century
2. wreck data is death report filed with National Ocean Service
3. records before 1945 sketchy
4. vessel descriptions rare
5. bias toward near-shore wrecks due to agency mission

HD

Advantages:
1. automated
2. locational accuracy good
3. vessel type specified where known
4. less bias toward near shore wrecks
5. updated regularly

Disadvantages:
1. primarily limited to 20th century
2. few soundings
3. no condition of wreck given

TAC

Advantages:
1. automated
2. locations assigned systematically where exact geographic position not known
3. excellent time range, 16th-20th centuries
4. large file (over 1700 entries)
5. updated

Disadvantages:
1. based primarily on secondary sources
2. few locations with high accuracy

Florida (BAR)

Advantages:
1. automated
2. vessel description and documentation of loss
3. excellent time range, 16th-20th centuries

Table II-1
(continued).

4. updated

Disadvantages:

1. based primarily on secondary sources
2. no condition given for wreck
3. limited accuracy in reported positions

Reports of the U.S. Life-Saving Service are another source of shipwreck information. This service began in the Revenue Marine Division of the Treasury Department in 1871 and eight years later came under a general superintendent who reported directly to the Secretary of the Treasury. Regulations required Keepers of Life-Saving Stations to report assistance rendered by their stations to any vessel, crew, or person and sent the originals to the General Superintendent of the service. The stations retained a copy of the reports. Annual reports of the Life-Saving Service contain narrative reports of services and tables of casualties occurring near life-saving stations. A microfilm copy of these tables is available for the period 1876 to 1914.

An act of January 28, 1915 established the U.S. Coast Guard by consolidating the Department of the Treasury's Revenue-Cutter and Life-Saving Services. Perhaps for this reason, Coast Guard records include copies of Life-Saving Service assistance-rendered reports for the period 1901 to 1915. These are arranged by fiscal year by Life-Saving Service district. Also with the Coast Guard records are microfilmed copies of assistance-rendered reports for the period 1916-1940. These are arranged by date of casualty in two groups: reports of assistance rendered and reports of miscellaneous services rendered. These 1916 to 1940 reports are available on National Archives Microfilm T-920 and, like the customs wreck reports, are indexed on National Archives Microfilm T-926.

Other federal records also have shipwreck or associated maritime information, Some shipwreck data can be found in records of the Lighthouse Service (Records Group 26).

2.3.2.b Document Sources, State and Private

Significant and diverse document holdings ranging across all the historic periods of the northern Gulf were found at: Old Spanish Missions Historical Research Library Collection (OSMHRL), Our Lady of the Lake College (San Antonio, Texas); University of Florida, P.K. Younge Library of Florida History (Gainesville); Texas Antiquities Committee Shipwreck and Map files (Austin, Texas); Mariners Museum Research Library (Newport News, Virginia); LBJ Library and Archives (Austin, Texas); De Zavala State Library (Austin, Texas); University of Texas Library (Austin, Texas); Sterling C. Evans Library, Texas A&M University (College Station, Texas); and Howard-Tilton Library, Tulane University (New Orleans, Louisiana).

2.3.2.c Document Sources, Foreign

The primary source for information on the Spanish period in the New World is the Archivo General de Indies (AGI) in Seville, Spain. It is known to the English speaking world as the Archive of the Indies. It is divided into sixteen major sections. Within each section, each *legajo* or bundle is assigned a number. Loose papers used to be left in whatever order the most recent user had adopted, but since the mid 1960's the staff of the Archive systematically organized them according to date and sequential *numeros.* The numeration of documents within the *legajos* has made it possible to cite a document by its individual number.

The Archivo General de la Nation (AGN) is the national archive for Mexico located in Mexico City. It contains both AGI and AGN documents. Many relating to New Spain have been reproduced and appear in repositories such as the P.K. Younge Library and at the Spanish Colonial Research Center, University of New Mexico, Albuquerque. The major secondary study cited in this report, *Seville et l'Atlantique* is based almost exclusively on AGI documents (Chaunu and Chaunu 1955). In France, the main sources of French maritime information are located at the Archives Nationales, Paris in the Archives des Colonies.

The Archives des Colonies in the Archives Nationals consist of a number of series of varying importance for the history of New France and Louisiana. The outgoing communications, including the orders, memoranda, and instructions of the king and the dispatches of the ministers, make up series B. The incoming communications, series Cl 1 A, "Canada et Dependances, Acadie, Ile Saint Jean et lie Royale, Correspondence Generale," is composed of the original documents received from the governors, intendants, officers, and other officials of New France.

The corresponding file for Louisiana, series Cl 3A, "Louisiane, Correspondence Generale," consists of correspondence received from officials in Louisiana and is similar to series Cl 1A in content. Series Cl 3A is also the main repository of documents relating to French activities connected with Texas, particularly the expeditions of Louis Juchereau de St. Denis, and contains much relating to Florida. The Archives des Colonies are essential for the history of the administration of the American domain, for its political, military, Indian, and church affairs, and for legal, social, and economic history.

Surrey (191 6) used these documents as the principal sources in her study of commerce in Louisiana which gives some significant data on shipwrecks during this period. These archives have been duplicated on microfilm by the U.S. National Archives and a set was found at the Howard-Tilton Library, Tulane University. For British shipwreck records, the Public Record Office (PROKew), is a repository of admiralty and foreign office documents such as dispatches and logs. Information on shipwrecks is available but not as extensive as that found at Guildhall Library, London. Other repositories include the Board of Trade, London and the Admiralty Library, Naval Historical Branch. Most records of shipwrecks have been abstracted into directory form such as *Lloyd's Registers,* Wreck Returns (Board of Trade), Admiralty Progress Books and Navy Lists (PROKew), and the Maritime Museum Wreck Registers (Greenwich),

A lesser-known abstraction of British records for the north Gulf is found in Rowland (19 11): *Mississippi Provincial Archives, English Dominion, 1763-1781* (1911). This collection of transcripts was made by the Mississippi Department of Archives and History, Additional data on the French period is found in three other volumes of the *Mississippi Provincial Archives* (Rowland and Sanders 1928, 1929 and 1932). The shipwreck data from the British sources were found mainly in the Mariners Museum Research Library collection with the exception of the Wreck Returns of the Board of Trade. No complete set of these returns is known for any data on wrecks in the United States.

2.3.3 *Directories*

A principal directory is *Merchant Vessels of the United States,* published by various government agencies since 1867 and currently published by the U.S. Coast Guard. These annuals contain vessel names under type of vessel (sailing, steam, unrigged, yachts, etc.), with details on rig, tonnage, dimension, when and where built, home port, and owner. There is also information on abandoned or lost vessels, those sold outside the United States, and on government vessels and shipyards. Complementary or similar directories include the *American Bureau of Shipping Records, General List of Merchant Shipping, Lloyd's Register,* and *Registre Veritas.* These give name of vessel, date built, builder, owner, size, tonnage, machinery on-board, flag of registry, and -- in later years -- official number and signal letters.

The principal foreign directories are Lloyd's List 1740-1970, Lloyd's Weekly Shipping Index 1880-1917, and Lloyd's Missing Vessel Books 1873-1954. Lloyd's List published all vessel movements and casualties reported to Lloyd's with customs house entries and much

other information, There is a microfilm index to the list for 1838 to 1926. From 1927 there is a card for each vessel on which all movements and casualties are reported. Lloyd's ***Weekly Shipping Index*** published voyage, engaged date of sailing and latest report for ocean going steamers and sailing vessels. The index also reproduced all casualty reports published during the previous week. ***Lloyd's*** *Missing* ***Vessel*** *Books 7873-1954* are manuscript records of ail vessels posted missing by the Committee of **Lloyd's** giving details of vessels, masters, crews, voyage, and cargo. For the more recent past, ***Lloyd's*** *Marine Loss Records 1939-1970* give details of all vessels lost with full reports as received at **Lloyds.** Many of these citations are found at the Mariners Museum, Newport News, Virginia.

Lytle and Holdcamper (1975) published a directory of ship losses abstracted for government documents contained in the U.S. National Archive and as enrollments, casualty reports, life-saving station reports, etc. This directory supplements the ***List of*** *Merchant* ***Vessels of the*** *United States* by covering the early period 1790-1868.

2.3.4 Descriptions

These are published accounts of individual shipwrecks. They are found in almost all repositories. Important, but difficult to systematically examine, they represent the most labor intensive aspect of shipwreck research as they are so scattered and uneven in detail. These are typically news accounts which may be the least biased of all shipwreck accounts (**Bourque** 1979),

Loch head (1951, 1954, 1958) abstracted several accounts from New York and **Boston shipping lists as well as news accounts of losses. While** more like a directory, these listings allow one to access the individual reports. These abstracts were found at the Mariners Museum Research Library,

2.3.5 *Secondary Literature*

Data for historic shipwrecks developed principally from secondary sources has limited value due to lack of validity. The most valid reports on shipwrecks are primary sources - news accounts, **official** reports, logs, or other direct observations of the specific shipwreck. To adequately research all primary source data for historic shipwrecks is beyond the resources of this study as it was for the CEI study. We examined collections of primary sources or facsimiles of these materials in a number of archives and libraries. We further restricted the study to only those archives in the United States, with the exception of the National Archives of Mexico (AGN) and Spain **(AGI).**

For Spanish shipwrecks excellent secondary sources were found in studies by researchers of the National Library of France (**Bibliotheque Nationale,** Paris) (**Chaunu** and **Chaunu** 1955), research done on the 1554 shipwrecks located in the Old Spanish Mission Research collection at Our Lady of the Lake College, San Antonio, and records of the Spanish Colonial Research Center, University of New Mexico, as well as newly printed **catalogues** of the holdings of AGN (Mexico City).

For the French shipwrecks of the colonial period we used the facsimile microfilm of the correspondence found in Archives Nationale, Colonies, Series 13, located at the **Howard-Tilton** Library, Tulane University. British losses were found in similar facsimile data of the London Board of Trade, **Lloyds.** Admiralty and Foreign Office reports were located principally at the research library of the Mariners Museum, Newport News, Virginia. American shipwreck data were found in a variety of sources at the U.S. National Archives and its branches, as well as **copies** located at Mariner's Research Library, the **DeZavala** State Library (Austin, Texas), the University of Texas Library (Austin), and the Sterling C. Evans Library of Texas A&M University. Sources in these repositories include the *Reports of the Steamboat Inspection* ***Service,*** *Reports of the U.S. Live Saving Service* (later U.S.

Coast Guard), *Official Records of the War of the Rebellion, Union and Confederate Navies* (ORN), and the *List of Merchant Vessels of the United States* (MVUS).

3.0 HISTORIC SHIPPING ROUTES

Shipping routes have been correlated with shipwrecks in **studies including** CEI (1977), SAI (1981), Bourgue (1979) and Pierson (1987). Fundamental in the correlation of shipwrecks with trade routes is the notion of economics and politics. European and later New World colonial ships sailed the Gulf for economic gain. Trade centers, termed "nodes," formed at principal river mouths and embayments such as the Mississippi River, Mobile Bay, Pensacola, Tampa, Biloxi, and Galveston.

Seaborne trade also existed in the Gulf before Columbus. Evidence in Pre-Columbian records suggest that civilizations practiced thriving coastal trade along the coasts of Mesoamerica. This commerce was conducted for hundreds of years using large seagoing canoes capable of navigating the shallow coasts of Mesoamerica. Travel between Mesoamerican and Gulf islands, later called the "Indies" by the Europeans, is evidenced by shared cultural traits and reports of Indian craft using sails and oars (Diaz del Castillo 1955).

The first European to sail the Gulf of Mexico was Sebastian de Ocampo in 1508 (Weddle 1985). The first navigator to transverse the "hidden seas" northern shore was Alonzo Alvarez de Pineda in 1519 (Weddle 1985). The first circumnavigation of the northern Gulf was in 1686 (Weddle 1987). During this period of over a century **and a half Spain increased its commercial exploitation** of the Gulf.

The Gulf of Mexico was a "Spanish Sea" for almost two centuries. The Gulf provided a sheltered sea route for Spain's economic exploitation of its "Nueva España" (New Spain) until the French colonization of the Louisiana Territory in 1699. From Vera Cruz to Havana commerce was developed that carried the wealth and resources of the "New World" back to Iberia (Hoffman 1980).

The summer southeasterly tradewinds and the Loop Current created a natural marine route for the Spanish. American treasure was the first trade good to traverse the Gulf (Figure II-3). It came principally from Mexico and Peru after the discovery of the fabulous Aztec and Inca mines. Its economic impact on the European world precipitated a price revolution (Hamilton 1934).

Spain's 16th century expansion and the effect of New World gold and silver on the European world system was closely linked to the reduction of costs and hazards of long distance voyages (Davis 1973; Mendelssohn 1976). Before this expansion trade over such long distances was restricted to low bulk, high value items (McGovern 1986). By the mid-1 6th century merchant vessels began to sail in fleets convoyed by warships (Hamilton 1934). Costs were borne from proceeds of the "averia," a special convoy tax levied on goods carried to and from the Indies (Veitia Lenaje 1681). The larger ships that were introduced at this time in response to the increasing volume of trade meant gradual abandonment of old routes. With the conquest of New Spain and Tierra Firme (Panama), vessels sailed from these new territories through the Straits of Florida and home to the continent. After 1519 and the successful voyage through the Straits of Florida by Ponce de Leon and Alaminos , Spanish fleets increasingly traversed the central Gulf on their way to Havana and then Spain (Weddle 1985, MacLeisch 1989). This route, documented by Chaunu and Chaunu (1955), is corroborated by original ship records.

Between 1519 and 1699, Spanish flotas crossed the Gulf from Vera Cruz to Havana (Figures II-3 and n-4a). For reasons of expediency (favorable currents and winds) and later necessity (protection from pirates) the Gulf route became fixed through the Florida Straits. It was only when the French entered the Gulf, first with the failed La Salle Colony (1 685) and then with Iberville's successful enterprise (1699), that new routes developed.

France developed new routes to her Gulf ports of Biloxi, Mobile and New Orleans fulfilling La Salle's dream to plant a French colony and exploit the strategic importance of the Mississippi River (Weddle 1986, 1987). The French routes ran first to the colonies on the Windward Islands and then to the Gulf coast (Figure n-4a). Their return was a mirror of their outward

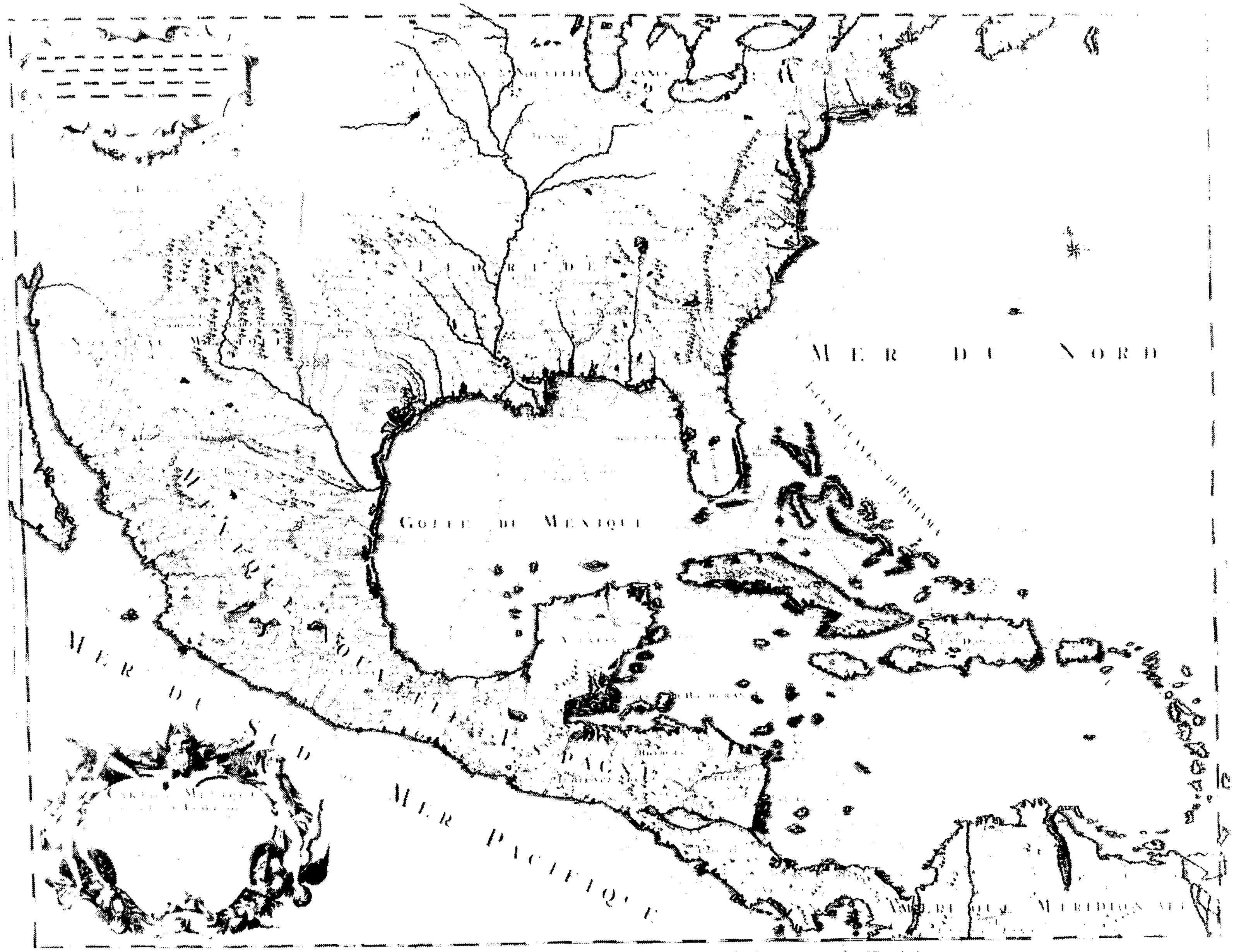


Figure II-3 1722 De l'Islé's map of Gulf of Mexico showing Flotas route journey (Surrey 191 6). By this mechanism, goods were shipped to and from markets in the islands, New France and the continent.

Like the Spanish, little if any variation occurred during the main French period (1699-1763) in the Gulf of Mexico. What variations did appear were the result of French attempts to develop trade with New Spain and Cuba. However, Spanish authorities resisted this commerce over the first half of the 18th century. Only the French in Mobile and their Spanish counterparts in nearby Pensacola proved an exception (Surrey 1916).

The principal ports of Mobile, New Orleans and Pensacola persisted throughout the turmoil of the late colonial period up to the beginning of 19th century. Coastal trade increased while the British and Spanish supplanted the French along the northern Gulf. A new cargo, negro slaves, was added to the American commerce of newly acquired Louisiana (1803) and Florida (1819),

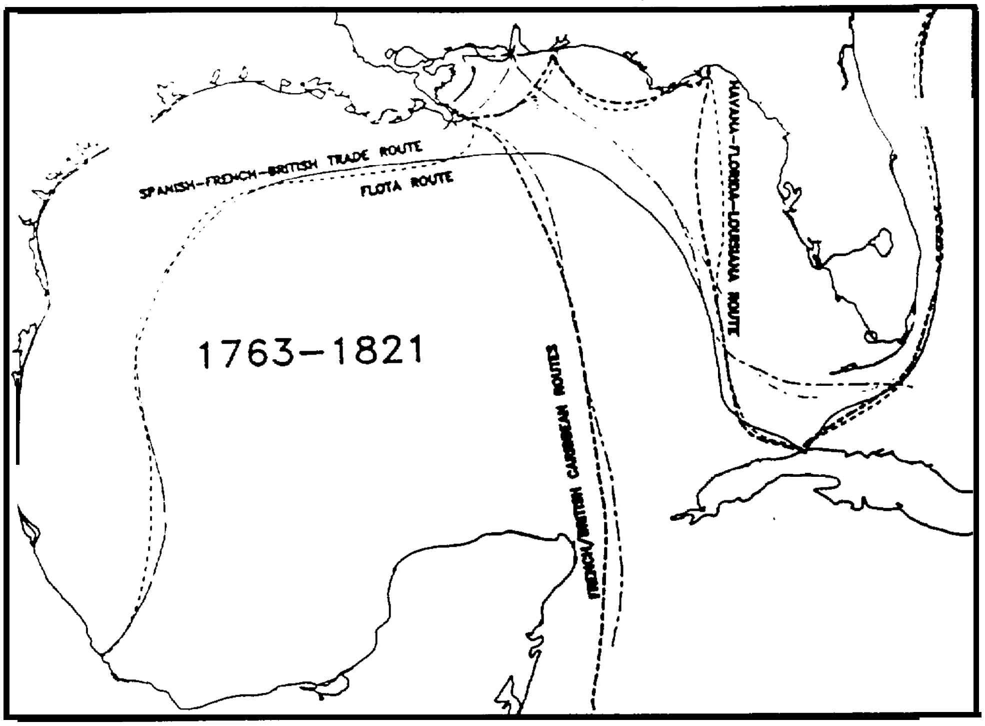
Along these coasts and that of the Texas Republic (1836-1845) more ports arose to draw lumber, grain, and cotton commerce. The period between 1830-1850 has been termed the “golden era” of the merchant marine of the United States. Due principally to the demand of the east coast and Europe for Gulf coast cotton, new lines developed to form a shipping triangle connecting the Gulf ports to New York and Europe (Figure 11-4 b). During this period New York came to dominate the shipping of the Gulf coast and this control did not cease until the Civil War began in 1861 (Laing 1974).

Normal commerce in the Gulf ceased when the Civil War began. This was due to 1) a naval blockade imposed on Southern ports by the Federal navy and 2) the huge profits to be earned by a successful running of this blockade. Coastal trade disappeared and was replaced by swift, low-silhouetted sail and steam vessels making direct dashes from ports such as Havana, Bermuda and Nassau. Their destinations were Brownsville, Galveston, New Orleans and Mobile (Coggins 1962). This anomalous pattern of shipping traffic persisted through the war period and then vanished.

After a reconstruction period, maritime commerce revived along the Gulf coast with traffic moving on coastal and direct routes to South American, European, Caribbean, and eastern U.S. markets. The southern U.S. ports established direct links to these extra-Gulf destinations breaking with the past reliance on New York’s control of the commerce (Laing 1974). Coastal traffic was restricted by law to U.S. vessels for the latter part of the 19th century but the American merchant marine never recovered its pre-Civil War prominence. The effects of Confederate raiders, lost markets, and increased costs (insurance, crews, and ship building) combined to allow a greater share of the trans-Gulf vessels to become foreign. Norwegian, British, Danish, Dutch, German, Italian and Columbian vessels called at southern ports defining new traffic patterns to new places like Tampa (1885) and Port Arthur (1897), Minerals such as phosphate (Tampa) and oil {Port Arthur) joined lumber, grain and cotton as exports from Gulf ports through the Yucatan and Bahama Channels (Table II-2). Tampa became a major Gulf port after the arrival of the south Florida railroad in 1885 with the concomitant entry of the Plant Steamship Line (Smyth 1898),

New economic vessel designs such as schooners and propellor driven steamers plied the Gulf at the turn of the 19th century. Commercial traffic on these routes continued throughout the first half of the 20th century with little change until the outbreak of World War II. From 1942-1943, German submarines preyed on traffic from Gulf ports moving east through the Florida Straits (Röhwer 1983). This traffic stayed principally coastal, with vessels leap-frogging along the rim of the Gulf to stay in the shallow waters and away from submarines (Victory at Sea 1952). With the end of the war, shipping patterns returned to normal and even more traffic entered secondary ports as well as those used in the 19th century. The goods carried changed over the century with oil-derived cargo supplementing agrarian exports in the western Gulf and grains or manufactured goods performing the same role at central and eastern Gulf ports (Center for Wetland Studies 1972, Sibley 1968). The principal axis of traffic shifted westward from the east-central Gulf to the west-central reversing the 19th to early 20th century pattern (Table II-3). A large factor was the opening of the Panama Canal in 1914, giving easier routes to west coast and Asian markets (Figure II-5).

One thing common to all these routes over the long period of more than four and a half centuries of commerce was the loss of vessels because of natural **and historic factors. It is ironic that as better technology** in vessel design replaced older designs, losses continue consistently to the present day.



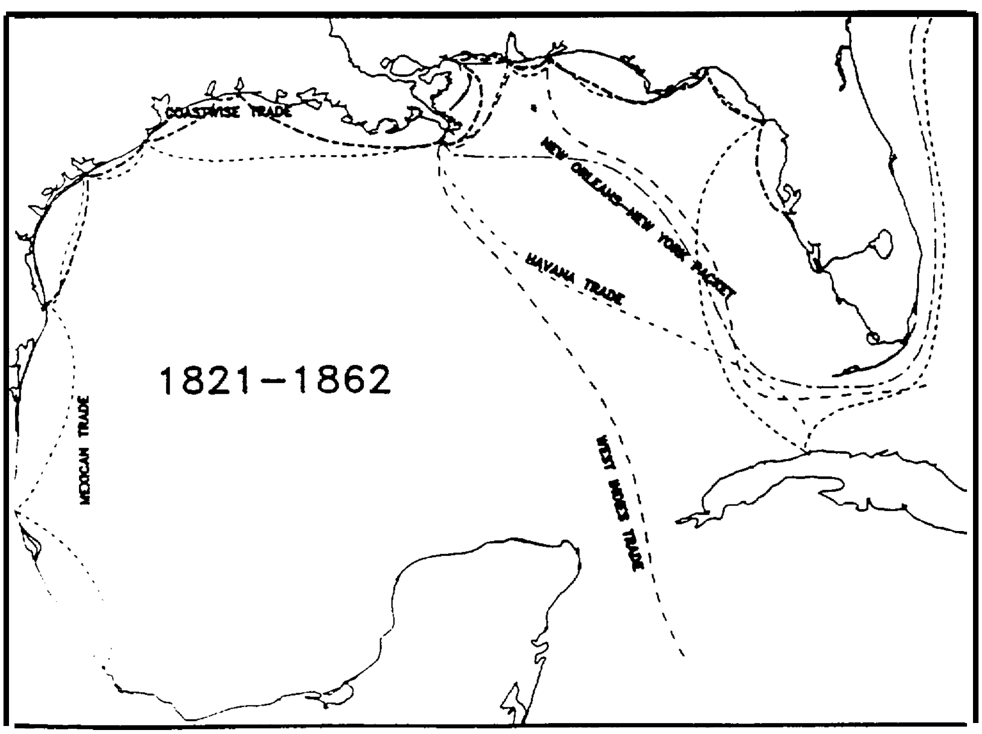


FIGURE II-4. (a) Shipping routes, 1763-1821
(b) Shipping routes, 1821-1862.

Table II-2.

SHIPWRECK CARGOES OF THE LATE **19TH - EARLY 20TH CENTURIES (SOURCE: LLOYD'S).**

Years	Cargoes	Origin/Destination	Registry
1891	ballast	Havana--> Pensacola	USA
1891	logwood	Jamaica--> Falmouth	Norway
1891	ballast	Rio--zShip Island	Germany
1891	ballast	Rio--zMobile	Norway
1891		Swansea-->New Orleans •	UK
1890		Cienfuegos-->New Orleans	Spain
1891		La Plata-->Appalachicola	UK
1891	coal	Pensacola-->Galveston	-
1891	-	Point a Pitre-->Appalachicola	USA
1893	logwood	Kingston (Ja.)-->Hamburg	Norway
1893		Santos-->?	Austria
1893	ballast	Progresso-->Pensacola	
1894	logwood	Belize--> LaHavre	UK
1894		Pascagoula-->Liverpool	
1894	ballast	Marseilles--> Pensacola	Norway
1894	wine	Barcelona--> Havana	Spain
1895	bananas	Ruatan-->Mobile	Colombia
1895	timber	Pensacola--> Rio	Norway
1895		Chiltepec-->? (off Corpus)	
1895	-	Mobile--zSanta Domingo	Colombia
1896	lumber	Pensacola--> Rio	Colombia
1896	lumber	Mobile--> Montevideo	Norway
1896		St. Paul de Loanda-->Pensacola	Austria
1897	lumber	Sabine Pass-->Schiedam	Holland
1898	crushed stone	New York-->Key West	USA
1898		Pensacola--> Messina	Italy
1898	pitch pine	Pensacola-->Cardiff	Norway
1898	lumber	Moss Pt. (MS)-->N.Y.	USA
1898	ballast	Barbados--zShip Island	Colombia
1899	·	Charleston--> Pensacola	USA
1899	coal	Baltimore--> Galveston	USA
1899		Appalachicola--> Boston	USA
1900	coal	Baltimore-->Galveston	USA
1900	mahogany	Santa Ana-->Channel	UK
1900	·	Dacquiri-->Ship Island	USA
1900	-	Cuba--sNew York	Denmark
1901	ballast	Cay Francis--> Mobile	USA
1901	ballast	Porto Plata-->Ship Island	USA
1902	ballast	Matanzas-->Pascagoula	Colombia
1904	ballast	Newport--> Pensacola	Italy
1904	pitch pine	Mobile-->Cienfuegos	Colombia
1904	ballast	Kingston-->Pascagoula	USA
1905	ballast	Buenos Aires--aShip Island	Italy
1906	-	Pensacola-->?	Germany
1906	wood	Pensacola--> Buenos Aires	Italy
1906		Mobile-->?	Italy
1906		Horn Island<-->?	?

Table II-2
(continued).

1906	lumber	Pensacola-->?	Norway
1906	lumber	Mobile--> Buenos Aires	Norway
1906	lumber	Ship Island-->?	Norway
1906	lumber	Ship island-->Buenos Aires	Norway
1907	lumber	Pensacola--> Montevideo	Norway
1907	ballast	Sandefjord-->Gulf port	Norway
1909	ballast	Buenos Aires--> Pensacola	Italy
1909	ballast	Ft. De France--> Gulfport ,	Italy
1909	ballast	Puerto Rico--> Mobile	USA
1910		Havana--> Pensacola	-
1911	lumber	Pensacola-->San Juan (P. R.)	USA
1912	ballast	San Juan--> Mobile	USA
1913	general; rice	Vigo-->Havana	UK
1914	phosphate	Tampa--zNew Orleans	USA
1914	ballast	Havana--> Gulfport	USA
1915	phosphate	Tampa--zNew Orleans	USA
1915	sisal grass	Progreso-->Mobile	USA
1915	lumber	Sabine Pass--> Boston	USA
1915	asphalt	Trinidad--> Gulfport (MS)	USA
1915		Gulfport-->Mobile	USA
1916	molasses	San Juan--sNew Orleans	USA
1917		Santa Domingo--> Pascagoula	Colombia
1917	phosphate	Port Tampa--> Matanzas (Cu)	USA
1918(?)	lumber	Gulfport-->Puerto Rico	USA
1919	pitch pine; lumber	Gulfport-->Genoa {Italy)	USA
1919		Mobile--> Genoa	USA
1919		Mobile--> Ponce (P. R.)	USA
1919		Punta Rasa-->Tampa	USA
1919	staves/iron	Mobile--> Lisbon	USA
1920	oil	Port Arthur, TX--> Mobile	USA
1920	lumber	Tampa-->Cuba	USA
1920	mahogany	Belize--sNew Orleans	USA
1920	ballast	Havana--zCharleston	USA
1921		Mobile--zHavana	USA
1921	oil	Port Arthur, TX--> Miami	USA
1921	ballast	Santa Domingo--> Mobile	Colombia
1921	ballast	Mobile--sSantiago	USA
1922	general	New Orleans--> Houston	USA
1923	lumber	Gulfport-->Havana	USA
1924		Jamaica-->N.Y.	USA
1924		New Orleans-->Sabine River	USA
1924	lumber/resin	St. Andrews, FL-->?	Italy
1925	lumber	Tampa--> Boston	USA
1925	lumber	Gulfport-->Puerto Rico	USA
1925	lumber	Mobile--zHavana	USA
1925	lumber	Pascagoula-->Trinidad	Colombia
1926	ballast	Miami--> Pensacola	USA
1926	ballast	Gulfport-->Mobile	USA
1927		Tampa--> Baracoa	Honduras
1928	liquor	Belize--s(Louisiana)	Canada
1930		Port Arthur--> Pensacola	USA

Table II-3

TRAFFIC OF GULF PORTS (1983-86)

	PORTS	TRAFFIC (no. of vessels)
1.	Galveston/Houston/Texas City, Tex.	11,710
2.	Mouth of Mississippi/New Orleans/ Baton Rouge, La.	3,906
3.	Tampa/St. Petersberg, Fla.	1,656
4.	Beaumont/Port Arthur, Tex.	1,181
5.	Mobile, Ala.	964
6.	Corpus Christi, Tex.	861
7.	Lake Charles, LA.; Freeport, Tex.	582
8.	Gulfport, Miss.	339
	Pascagoula, Miss.	312
9.	Boca Grande, Fla. (Charlotte)	134
	Pensacola, Fla.	
	Brownsville, Tex.	114
10.	Carrabelle, Fla.	
	Key West, Fla.	46

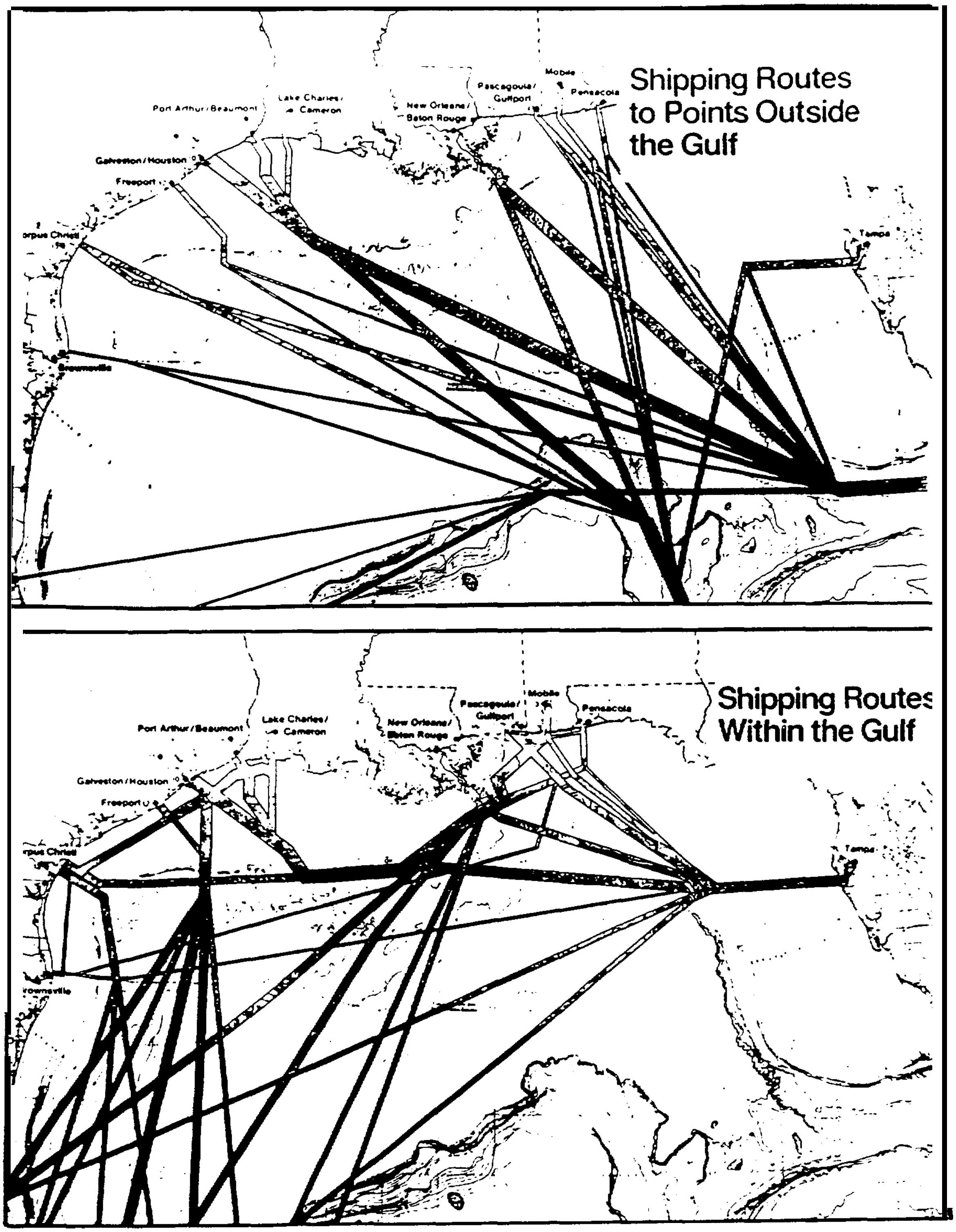


FIGURE II-5. Modern shipping **routes,** Gulf of Mexico (after NOAA, 1987).

4.0 HISTORIC PORTS, HARBORS AND NAVIGABLE WATERS

This study reviewed the establishment of historic ports, harbors, and navigable waters where shipwrecks are likely to be concentrated utilizing historic maps and literature sources listed in Appendix B. It is difficult to consider these factors independently from shipping routes. As discussed in the preceding section, ports act as nodes along trade routes. Maritime transport networks cannot exist without ports. Their variability is derived from specific economic and geographic relationships in the transport network. Simply illustrated, the early Spanish Gulf trade route included the ports of Vera Cruz, Havana and Cadiz. As the colonial period continued, ports developed along the Gulf rim and the trade networks became more complex. A hierarchy of trade centers developed as coastal traffic increased. The size of the ports were largely a function of the size of port facilities and the navigability of its harbor.

The ultimate determining factor for the location of a port is its position relative to the specific economic goods such as natural resources, manufactured items and services. In the early period of the post-Columbian era, posts such as Vera Cruz, and its San Juan de Ulua harbor, developed as distribution centers for the plunder looted by Conquistadors (Figure 11-6). Later, Vera Cruz became the principal port for gold and silver extracted from the mines of central Mexico. Havana developed as a port along the treasure route through the Straits of Florida and became the principal assembly point for the New Spain and Terra Firme fleets.

As French interests increased, Gulf ports developed in natural harbors with clear channels at: (1) Biloxi 1699, (2) Mobile Bay, 1701 and (3) Dauphin Island 1699 (Hamilton 1910). By 1717, New Orleans was established at the Balise on East Pass. The Spanish developed Pensacola in 1698 after La Salle's failed colonization attempt (Figures II-7 and II-8). British and American control of these ports began in the early 19th century. New ports followed settlers into Texas and Florida. Familiar names such as Galveston (1821), Tampa (1831), Key West (1822), Brownsville (1849), Corpus Christi (1848), Pascagoula (1870s), Gulfport (1887), Port Arthur (1897), Lake Charles (1803), and Velasco (1831) appeared along the Gulf. Other ports arose and faltered: Indianola (1844-1886); Cedar Key (1860's-1880s); and Grand Chenier (1870-1920s) (Table II-4).

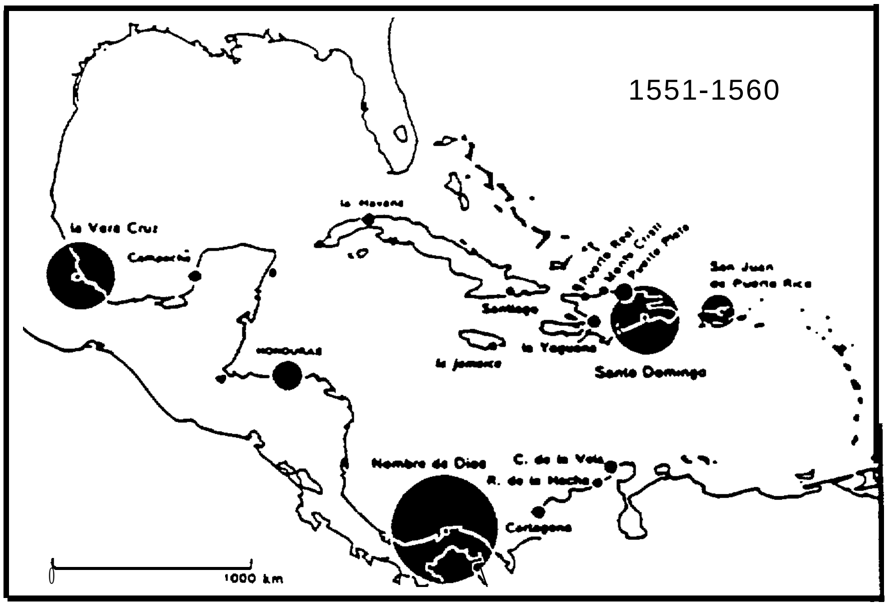
The major problems in accessing these ports was in their shallowness. The Mississippi River, with its birdfoot delta and numerous passes, posed a particular problem for mariners. It was only with Iberville's ascent of the river in 1700 that its navigable nature was ascertained. The Spanish had always associated the Rio Espiritu Santo (their name for the Mississippi) with a non-existent bay. This misconception was finally corrected after the circumnavigation of the Gulf by Iriarte and Enriquez in 1686 during their search for La Salle's failed colony. Their voyage defined the true nature of the river's deltaic complex (Weddle 1987). Even with this knowledge, the Spanish never grasped the economic and strategic importance of the Mississippi River to the control of the northern Gulf of Mexico. This is particularly ironic since De Soto's men retreated down the river to the Gulf in 1541 but did not appreciate what they had done. The river's importance was realized by Rene-Robert Cavalier Sieur de La Salle in his determined efforts (1 681, 1685) to exploit the great river for the development of vast areas of New France.

The commerce that flowed from these northern Gulf ports began slowly. The French, and later the British, recognized the importance of trade with the Spanish (Rowland 1911) throughout the 18th century. As local political and economic revolutions impacted the Gulf coast of Mexico (1816), the United States (1776-1789), and Texas (1836), so did the geopolitics of the Old World. The War of 1812 arose as a consequence of the Napoleonic wars. Piracy increased in the Caribbean markets of American ports as well as in the Gulf (Lafitte 1810-1821). Over 800 American ships were seized by the French using courts, privateer and warships when the U.S. defaulted on its first international treaty (Roberts 1974).

An American naval presence emerged in the Gulf with the eviction of Lafitte from Campeachy (Galveston island) in 1821, the clearance of the Bahamian Channel pirates in 1825, the support of Seminole Wars in Florida and the Mexican War (1845-46). Strong fortifications were built at northern ports to guard harbor entrances and channels. By the Civil War these forts and harbors became the target of powerful fleets. If the port could not be taken it was blockaded. The Gulf shore is dotted with shipwrecks which failed in running the blockades (Appendices C and D).

The commerce of war gave way to a return to export/import activities that drew larger and larger vessels to these ports. "Deep water" became the rallying cry for the competing ports of the coastal states. Dredging began with William Eads at Southwest Pass, and the Corps of Engineers continued at ports along with the Gulf (Gould 1889). Passes were modified, new ones cut, and old ones allowed to fill as man and his engineering skills altered the natural harbors and channels to meet the changing demands of maritime commerce and technology. This has meant a greater occurrence of historic shipwrecks in waters further from the Gulf shore. The **larger vessels required by the growing ports became** more restricted to specific entrance channels and less natural navigable water was open to them along the shallow coast. Ships that strayed too far from open fairways or dredged channels were often wrecked.

In summary, accessibility to Gulf ports determined the size and number of vessels as much as the kind of goods shipped at these ports. Transport costs decreased as vessel size increased which influenced the change in vessel types, active ports and shipping routes with time. This is reflected in the historical evolution of ports and vessels in the Gulf where galleons replaced naos **and caravelles, schooners replaced brigs and barques, and steam or oil carriers replaced sailing vessels (Appendix E).**



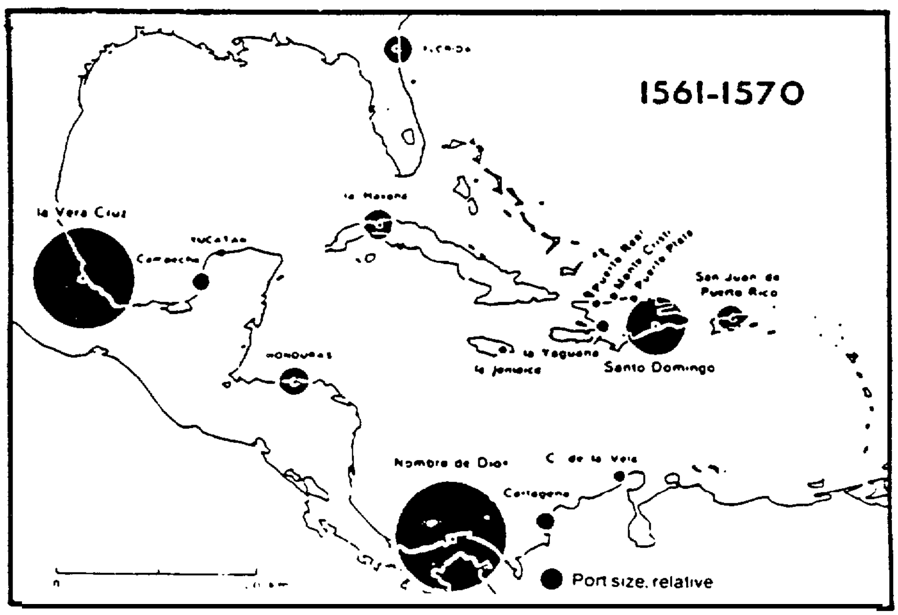


FIGURE II-6. **Spanish port development, 16th century.**

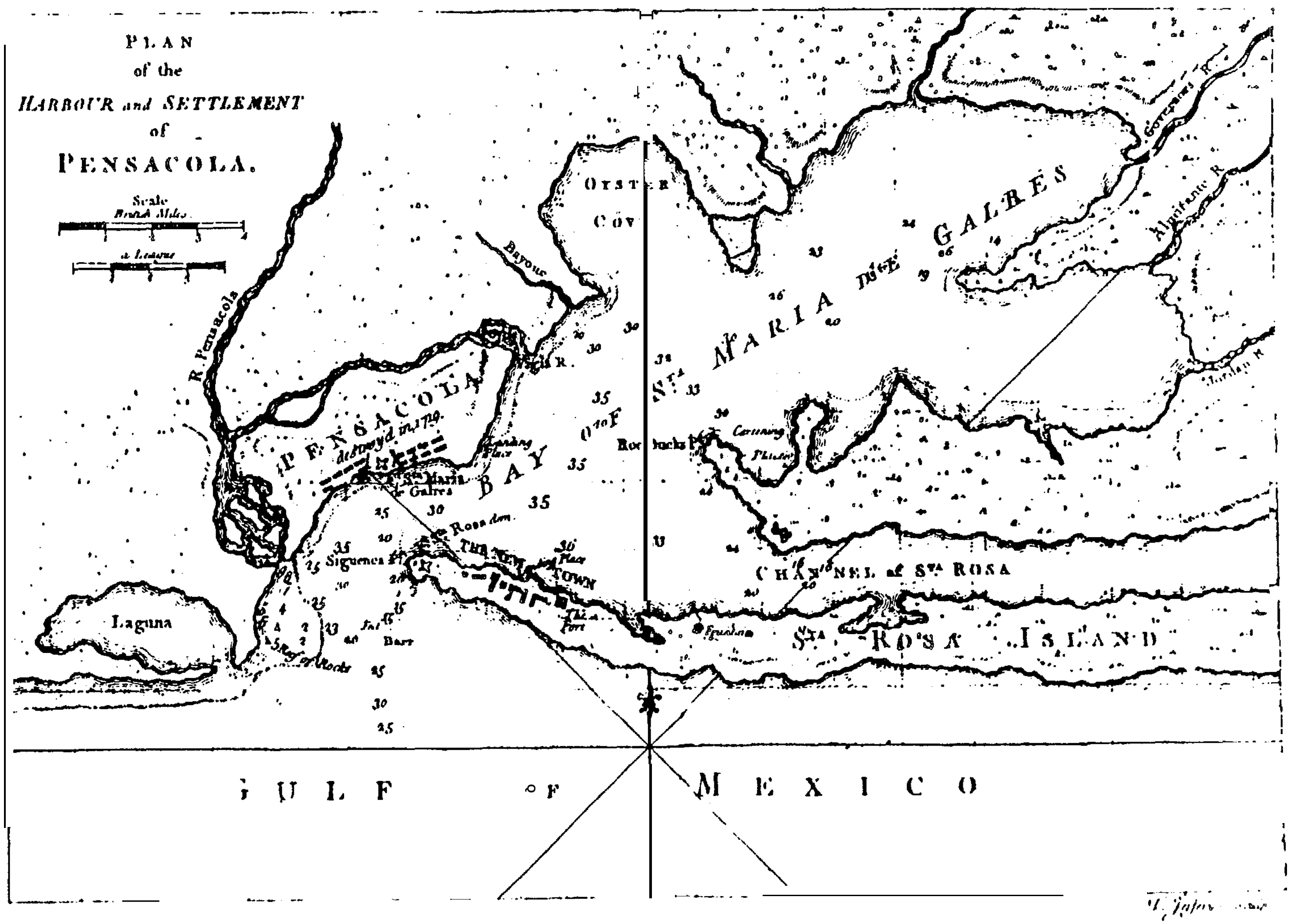
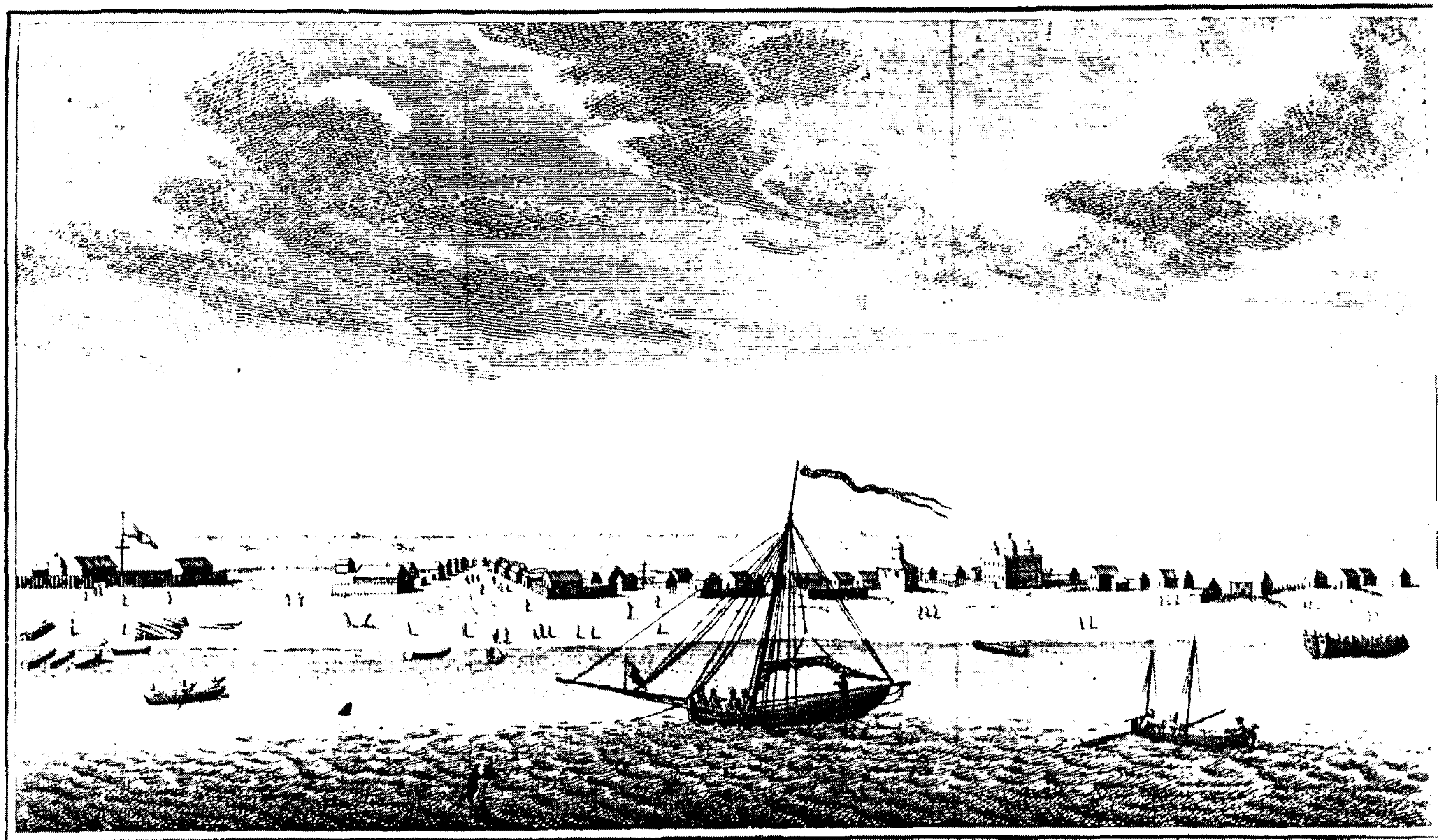


FIGURE II-7 Plan of the harbour and settlement of Pensacola, late 18th century



Gezigt van t Spaansche Vlek PENSACOLA, aan de Baay van eenen naam in de Golf van Mexiko, beoosten den uitloop van de Rivier Missisippi.

Figure II-8 Pensacola, 1743

Table II-4.

DATES OF FOUNDING OF HISTORIC PORTS OF THE NORTHERN GULF OF MEXICO (AFTER CEI, 1977).

Texas Ports
- Galveston (1816/21)
- Houston (1836)
- Freeport/Velasco (1830's)
- Indianola (1844-1886)
- Sabine (1840)
- Port Isabel/Brownsville (1840's)
- Port Aransas (1820/1839)
- Corpus Christi (1845)
- Port Arthur (1897)
- Port Lavaca (1900's)

Louisiana Ports
- Balise/New Orleans (1718)
- Grand Terre (1810-21)
- Lake Charles (1803)
- Morgan City (1850)
- Grand Chenier (1870-1920's)

Mississippi Ports
- Biloxi (1699)
- Pascagoula (1870's)
- GulfPort (1887)

Alabama Ports
- Dauphin Island/Mobile (1699/1710)

Florida
- Pensacola (1699)
- Key West (1822)
- Cedar Key (1830-1890's)
- Tampa (1831)
- San Marcos-Apalachee (1631)
- Apalachicola (1821-1865)

5.0 BARRIERS, SHOALS, BARS, AND REEFS

5.1 Historical Perspective

The early Spanish observers thought the coast line of the northern Gulf of Mexico was a continuous peninsula with a large river flowing behind it. As late as 1686, the Spanish continued to misjudge the nature of the coast and persisted in assuming the extenuated body of water inside the sand beaches (barriers) to be a river paralleling the coast from the Rio Maupate to the Sabine (Weddle 1987). Even when French cartographers such as Claude and Guillaume De I'Isle began showing barrier islands in the 18th century, Spanish maps continued to represent a solid, unbroken coastline (MacLeisch 1989; Weddle 1987).

This is understandable, for the Spanish made little effort to settle this northern coast until the French incursion beginning with La Salle (1685) and Iberville (1699). Their knowledge improved markedly after the 1686 voyage of Rivas and I riarte who entered all “bays, bars, and river mouths” in their circumnavigation of the Gulf (Weddle 1987). While searching for the La Salle colony of Matagorda Bay, Texas, the Spanish completed the exploration of the Gulf begun by de Leon and de Soto in the 16th century. The Spanish had always understood the nature of the reef chain along the northern aspect of the Straits of Florida. Their vessels had braved these hazards on the return to Spain since the 16th century (Chaunu and Chaunu 1955; McDonald and Arnold 1979) and Alaminos successfully charted the route through the straits in 1519.

To the French observer of the early 18th century, the whole Louisiana coast was skirted by a beach of little sand banks forming a double coast (Chaville 1903). The coast from the Rio Grande to the Florida Keys was “so flat that it can hardly be seen at a distance of two leagues and it is not easy to get up to it” (Raynal 1915). These early French observers correctly describe the shoreline and coastal waters of the northern Gulf, particularly those east of the mouth of the Mississippi River. In 1700, the French observed the overall shallowness of the coastal waters and many sand bars, particularly those at the mouths of the Mississippi . They further noted the “little depth of water” in “the constantly changing” river mouths (passes) which had not more than three meters of water (Raynal 1915). They encountered the same problem at Biloxi Bay where only shallops of less than a hundred tons could enter (Surrey 1916). By the 18th century, navigators were aware of the hazards of the coastal Gulf.

5.2 General

Formed by the interaction of sea level, waves, winds, currents and sediments, natural shoals and barriers make it difficult to navigate the deep channels between them. These coastal features are dynamic. This is not to imply that barrier islands, river inlet bars, sand shoals, and coral reefs migrate about the shore to impede shipping. In fact, Shepard (1960) observes that barrier islands have been relatively stable along the western Gulf on charts from about 1780 to 1880. In the Mississippi delta area, some islands disappeared to the advancing deltaic fronts and others, such as the Southern Chandeleur islands, disappear and reappear but these natural incidents are more the exception than the rule in terms of shoreline change. More changes have been noted in the barrier features of the Texas Gulf coast due to man-made activities such as dredging and jetties (McGowen, et. al. 1977).

Natural factors such as storms modify the barriers. The migration of headlands and bars alter channels while inlets can be completely closed after storms. An example of this latter case is the old Corpus Christi Pass (Morton and McGowen 1980). These natural features present a hazard to ships and are locations for historic shipwrecks as determined during this study. Even when the bias from increased reporting frequency for shallow **coastal shipwrecks compared with that** of wrecks in deeper open water is eliminated, the natural hazards of the coasts are clearly the most important factor in explanation of shipwreck density. This is particularly so where maritime traffic patterns extend near hazardous shoals or reefs. Again, examining shipwreck location data from a chronological perspective, we see the convergence of historic shipwreck density with these maritime hazards.

In this study, we examine the nature of these natural hazards, relying on the work of others in the area of sediment and coastal geology. Historic maps, charts, and documents were used to discuss particular features and their importance to the location of historic shipwrecks. Historical changes in the shoreline were examined and related to the occurrence of shipwrecks (Appendix B).

The processes underlying this scenario of change are discussed. Specific topics include the Mississippi delta complex, changing channels between barriers, bars and mudflats, headlands and shoals, and, reefs of the Straits of Florida. These 307 km of natural navigation hazards became a principal cause of wrecks in the Gulf.

5.3 Shoals and Bars

Shoals and bars are prominent all along the northern Gulf coast. Shipwrecks in the Gulf occurred when vessels approached too close to these features and became stranded. These features are formed by the dynamic relationship between shoreline orientation, wave direction, and longshore sediment transport (McGovern, Garner and Wilkinson 1977). Channel bars and shoals form where rivers discharge into the Gulf such as at the entrance to Mobile Bay (Otvos 1982). These features vary according to the available sand budget and currents. These geographic forms are especially hazardous to mariners because of their ephemeral nature (Figure II-9).

Four major shoal complexes are: (1) the “Quicksand” and the Marquesas; (2) the shoals of Cape San Bias; (3) the entrances of the Mississippi River; and (4) the submarine delta of Mobile Bay.

(1) Dry Tortugas/Marquesas - Located southwest of the Florida keys, this area has the largest number of shipwrecks in the Gulf (Bearss 1971). Described by Hutchins (1784) and Romans (1775) these shoals were recognized as hazards very early in the history of the Gulf. Vaughn (191 4) describes the Tortugas having a lagoon only 3 m deep. The Marquesas lie west of the Rebecca Channel and the Tortugas west of the Boca Grande Channel. Of the two areas, the Marquesas have less coral and more shoals interspersed with carbonate detrius. The two complexes are crescent-shaped formed by- the west flowing counter current (Figure II-1 O).

(2) Cape San Bias - Shown in Figure 11-11, Cape San Bias is a cuspate foreland (Shepard 1960). Southward of the Cape extends a large shoal area. The Cape formed a natural danger for coastal traffic from east of the Mississippi to Tampa or Key West. The data from this study indicates it was less a hazard than the southern Florida shoal areas. The difference is in the opportunity for seaward movement by vessels in rounding the headland without interference by currents such as seen in the Straits. Vessels still sank at or off the Cape in such numbers as to single it out as a hazard area and therefore a moderate-high probability zone for historic shipwrecks.

(3) Mississippi River Delta - (Figure II-1 2) The whole deltaic area could be termed a large shoal or bar protruding across the shelf onto the slope and beyond. Coupled with the shoals and changing condition of the various passes, the delta presented serious problems to all historic navigators. Charlevoix (1766) attributes the origin of the passes to the river bar located at Head of Passes. The modern delta has advanced and distributaries such as Southeast Pass have dried up since early Gulf exploration (Scruton 1960).

With the founding of New Orleans in 1718 (Otvos 1982, Charlevoix 1766), the delta and its passes evolved to the commercial route we see today. Ships have stranded on the mudflats and shoals near shore or in the large shallow bays flanking its principal distributaries, Seaward of these entrances are deep unobstructed waters. This abrupt transition from the shallow coast to the deeper Gulf presented open water dangers to unwary craft during storms, Vessels rounding

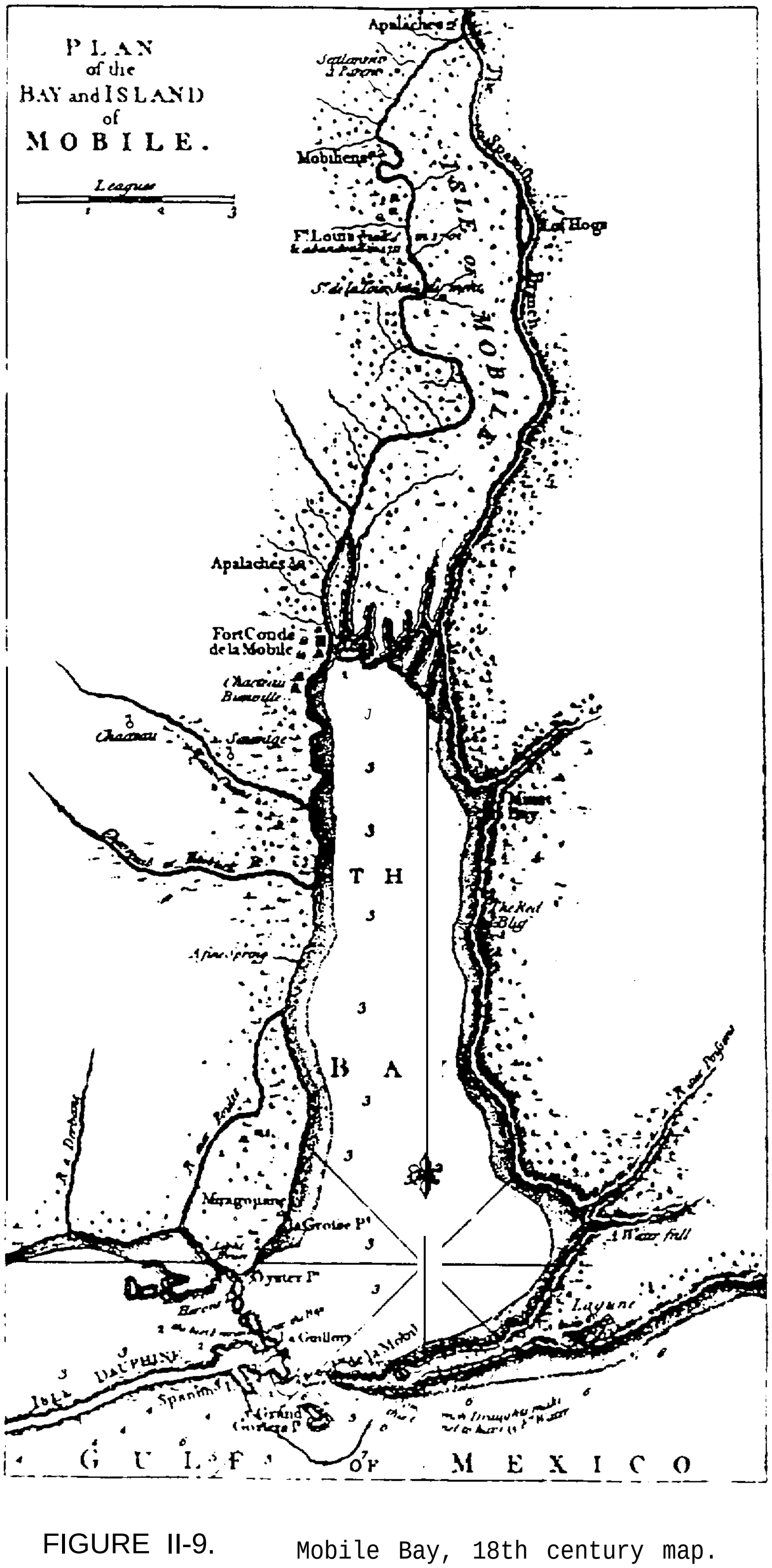


FIGURE II-9. Mobile Bay, 18th century map.

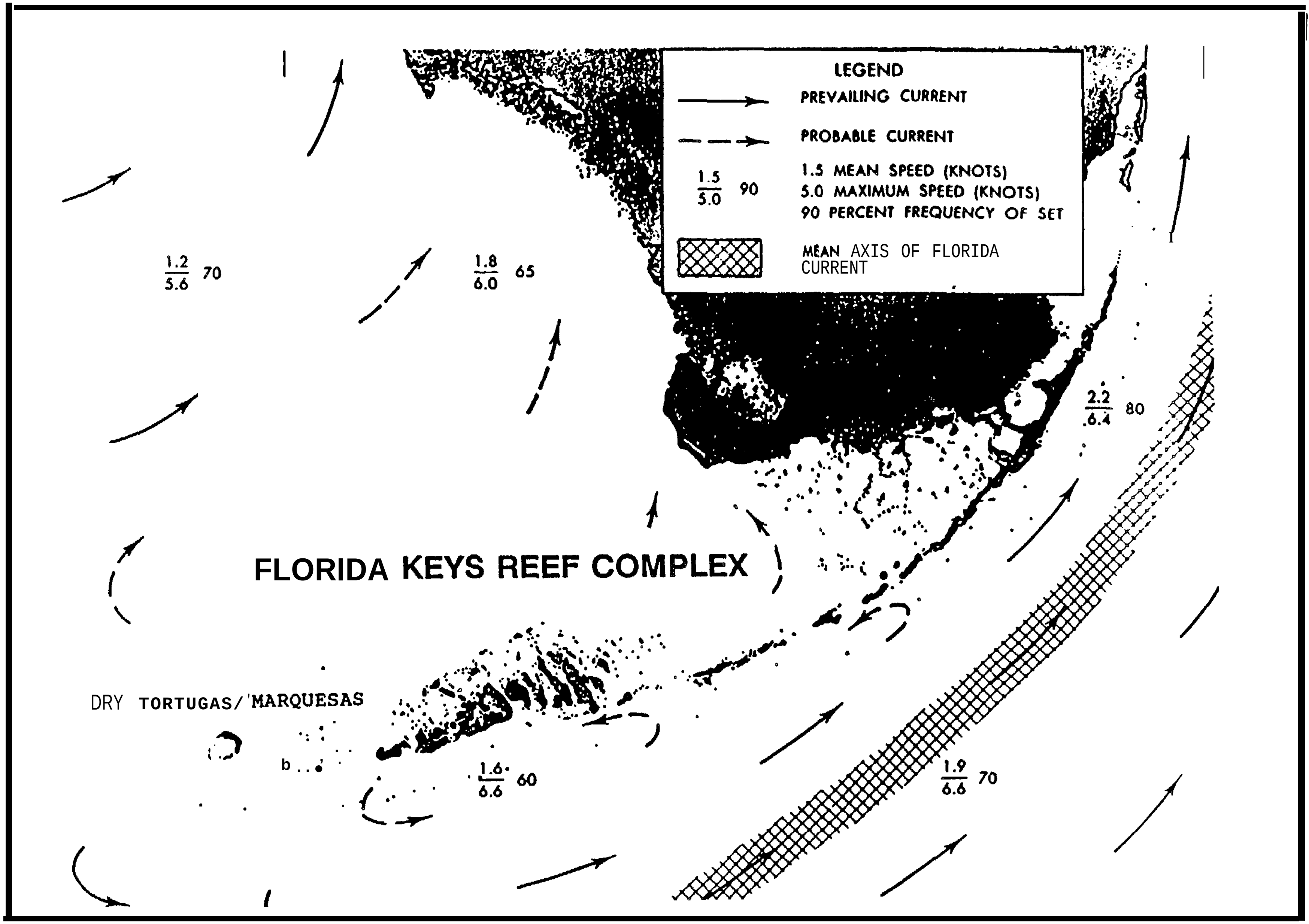


FIGURE II-10. Florida Reef Complex, Dry Tortugas and Marquesas.

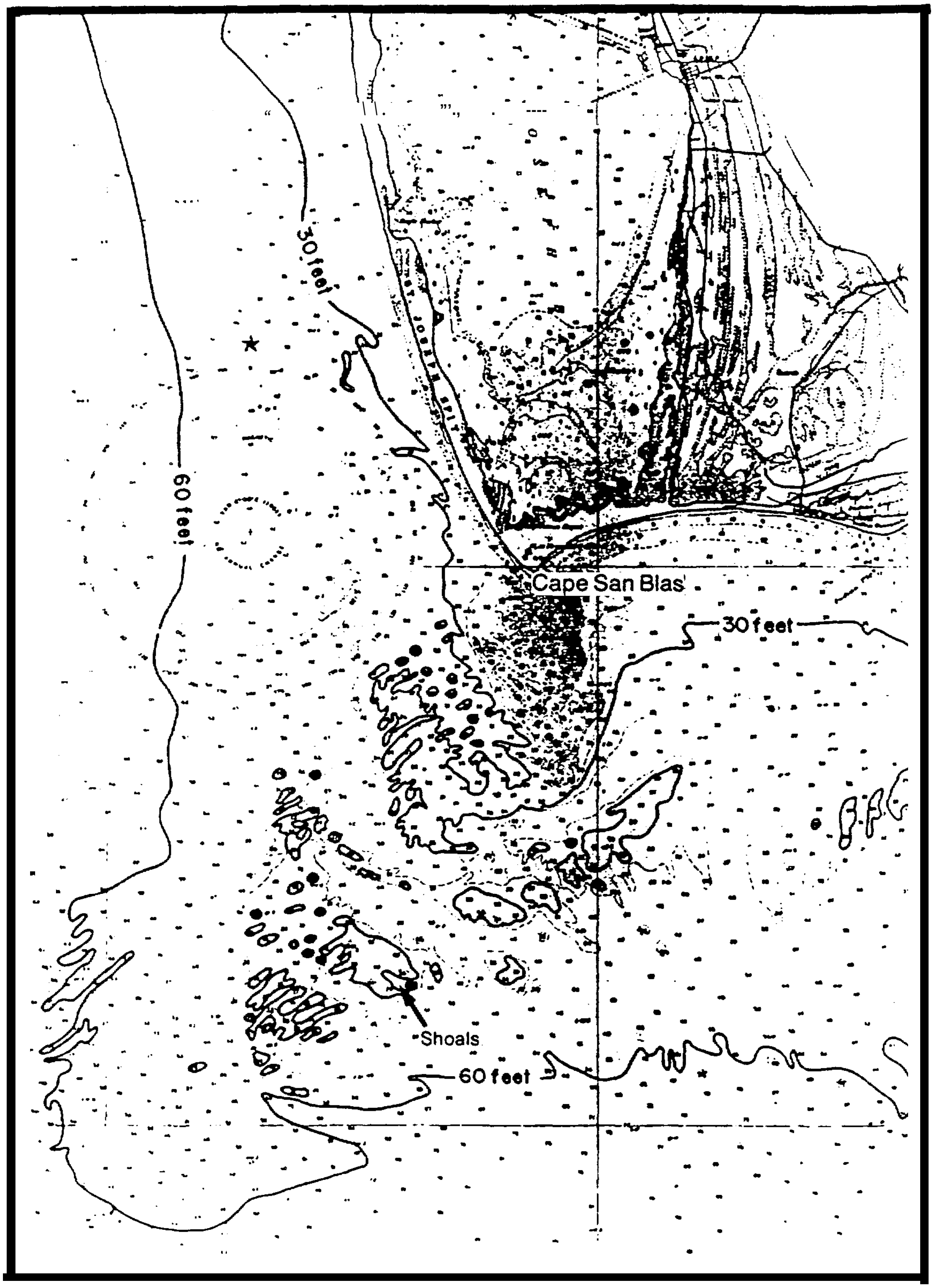


FIGURE 11-11. Cape San Bias (Florida).

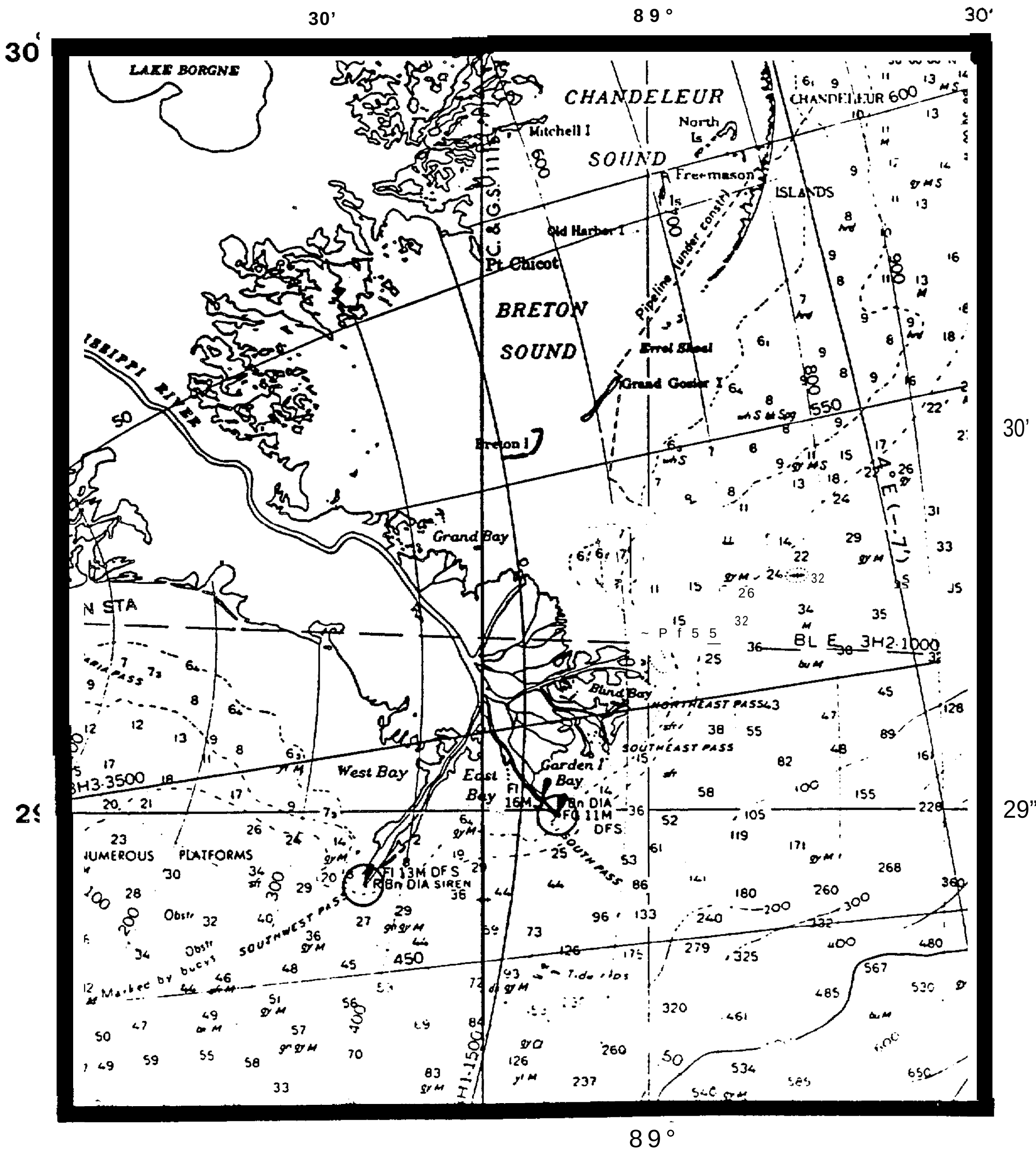


FIGURE II-12. **Mississippi River Delta.**

the delta could encounter rough seas with only the shallow waters and numerous mudflats or shoals as a lee shore.

The data shows a pattern of loss to either side of the deltaic tip. The pattern suggests strandings as the principal type of wrecking process rather than open water foundering. The heavy modern traffic pattern developed slowly from the 18th century with losses distributed to the east of the Balise (Northeast Pass) and along the Chandeleurs as would be expected for the French Colonial era. Only after the development of Louisiana ports and ports west of Sabine in the 19th century did shipwreck density begin to approach that of eastward waters.

(4) Mobile Bay Delta - (Figure II-9) Mobile Bay discharges roughly 85 percent of its outflow into the Gulf of Mexico forming a 10 kilometer wide delta seaward of Dauphine Island (Otvos 1982). The delta has numerous shoals and islands that change shape, disappear and reappear, much like the Chandeleurs, depending on conditions. Storms, in the past, completely closed the entrance channel to ships drawing more than three meters (Summersell 1949).

5.4 Barrier Islands

Shepard (1960) divides the barriers of the north coast into (1) long, straight, or smoothly curved (Texas); (2) segmented with wide passes (Louisiana, Alabama and Mississippi); cuspate headland or spit (Cape San Bias, Cape St. George); or lobate/cresentic (Southwest Florida), These barriers are generally sand facies lying between two mud facies. Their overall position between 1870-present changed little although locally they have fluctuated in length, growing westward, eroding eastward particularly in the northwest Gulf.

Otvos (1982) modifies Shepard's theory on sand sources for the barrier islands by including the sediment discharge of Mobile Bay as a key element for barrier nourishment east of the Mississippi. Otvos echoes Shepard in the assessment of a relatively stable barrier coast, although he places more emphasis on the processes of segmentation and emergence/submergence. He speculates that the permanent separation between Petit Bois and Dauphin Islands occurred during a storm, possibly in 1740. The H.M.S. MENTOR cruise in 1780 used a 1744 map that still showed Petit Bois and Dauphin Island as one island (Gauld 1803). Otvos' date for their segmentation is wrong (Figure I-I O). The separation probably occurred between 1744 and 1803, Ship Island was a single island in the past but is separated into two elements today.

The Chandeleurs are examples of emergence/submergence (Figure Ii-I 3). Westward of these Mississippi barrier islands instability is seen in changes in passes such as from the islands along the Texas coast. Changes in Texas barrier islands include 20th century dredging (Morton and McGovern 1980). The distribution of shipwrecks along the barrier islands is remarkably uniform and reflects a higher incidence of coastal casualties due to inter-Gulf traffic that is concentrated near western Gulf ports.

5.5 Reefs

As discussed earlier in this section, the Straits of Florida represent the area of greatest shipwreck concentration in the Gulf. This area was the principal egress for the Spanish and has proven to be the greatest natural maritime hazard in the Gulf of Mexico. The reef complex, including the Marquesas and Dry Tortugas, stretches 322 km (Figure II-IO). While the principal surface currents of the Straits of Florida are dominated by the Florida Current component of the Gulf Stream, numerous counter currents and eddies create a hazardous channel. This was first observed by Antonio de Alaminos, pilot of Ponce de Leon’s 1513 expedition (Weddle 1985). The eastward flow of traffic grew from the 16th century because the current allowed the early vessels to make progress against the westerly blowing trades just as it aids modern ships to increase speed and conserve fuel.

Agassiz (1852) described the reefs as a "series submarine elongate hillocks rising above sea level in the form of islands in places." These reefs have changed over time. One example is Looe Key, 12 km southwest of Big Pine Key. Exposed in the 19th century, it has disappeared (Wheaton and Jaap 1988). This key has taken its name from the 1744 wreck of the HMS LOOE, a 44-gun British Frigate, one of many wrecks along the reef complex.

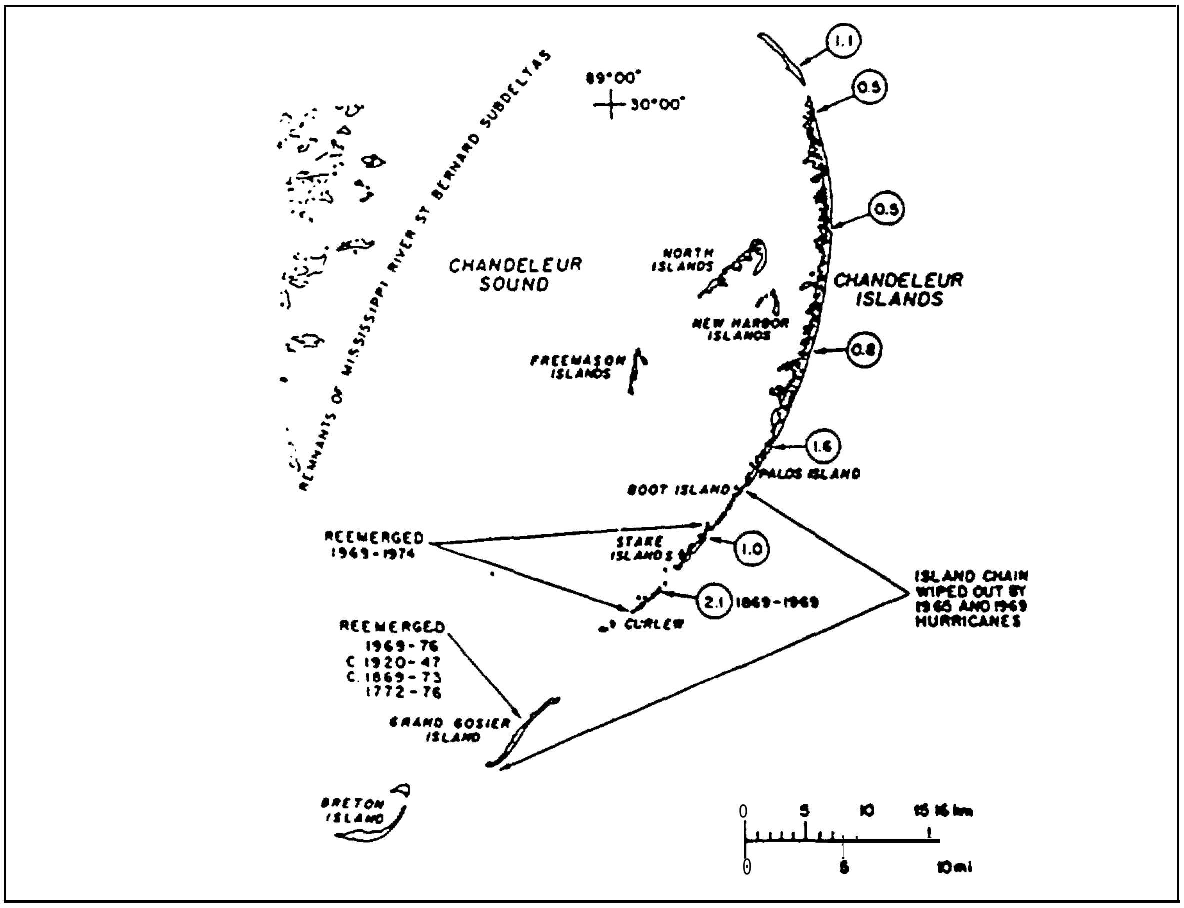


FIGURE II-13. **Chandeleur Islands.**

6.0 WINDS, CURRENTS, AND WAVE ENERGY ZONES

This chapter discusses factors significant to the cause of shipwrecks as well as to their preservation within the marine environment. Historic sailing vessels either sailed into unfavorable winds or rode favorable seas. Wind strength, direction, and the subsequent current shears were determinant factors in a vessel's final track across the northern Gulf. Longshore currents can run either parallel or contrary to swells depending on prevailing winds. Mariners balanced these natural forces with a cruise track which provided both economy and safety for their ships. When they failed, a shipwreck occurred.

Once the vessel sinks, it is subject to shallow water physical processes such as wave height which in turn depends on wind velocity. One can examine illustrations such as Figure 11-14 where wave and storm wave heights indicate statistical patterns for the Gulf. Where these wave related water movements are frequent and strong we can assume rapid deterioration of a shipwreck.

6.1 Historic Perspective

Gauld (1796) cites Lorimer (1769) for an early description of the Gulf of Mexico wherein the Gulf is considered as "one great whirlpool." Here the Gulf Stream is termed "the stream of the Gulf of Florida". This early description, while somewhat simplistic, characterizes the Loop Current as a river of water flowing through ambient Gulf of Mexico water (Molinari, et. al. 1975).

The technology of ships and navigational equipment available to sailing vessels required that natural wind patterns and current be used whenever possible (Hoffman 1980). No ships of the early 16th to 18th centuries could point very well. De Camp (1963) observes that early sailing vessels could sail one point (1 1°) into the wind if the ship had a deep keel to keep it from sliding sideways. Modern square rigs can make two points, while fore-and-aft rigs can make three points (330). Even by 1815, square rigged vessels such as brigs could not sail a " course in the Gulf of Mexico as easy as a fore-and-aft rigged schooner (Faye 1940).

Navigational instruments of the 16th and 17th centuries could determine latitude but longitude was problematic until the development of accurate chronometers in the 18th century (Sea Technology 1986). Logs and lead lines were used for speed measurement and depth soundings. Compasses were a primary aid. So to reach the Florida Straits and exit the Gulf, sailors had to reach across the tradewinds in vessels that varied greatly in sailing qualities. Ships traveling east to west in the Gulf could take advantage of the prevailing winds but then had to deal with the Loop Current. Winds, currents, and the weather patterns of the Gulf to a large degree determined the pattern of commerce (Hoffman 1980). Hurricane season limited west to east sailings to late spring or early summer (March to June), while winter fronts restricted activity from November through February. Late August to late November was used, but October was known as a period where hurricanes could readily spawn (Chaunu and Chaunu 1955). As for winter, in 1564, the Spanish Admiral, Don Garcia de Toledo wrote: "It is a fact clearly established that all sea expeditions in winter are a complete waste of money..," (Flanagan 1987).

6.2 Winds and Currents

Circulation in the Gulf is complex, especially involving the interaction of the Loop Current and associated eddies (U.S. Department" of Interior 1983). The Loop Current exits the Gulf through the Straits of Florida and its associated reef complex (Figure 11-15 and Figure 11-16).

The Gulf is characterized by an "offshore" or open Gulf and an "inshore" or shelf area energy regime. The open Gulf is influenced by the Loop Current, eddies, a semi-permanent gyre in the

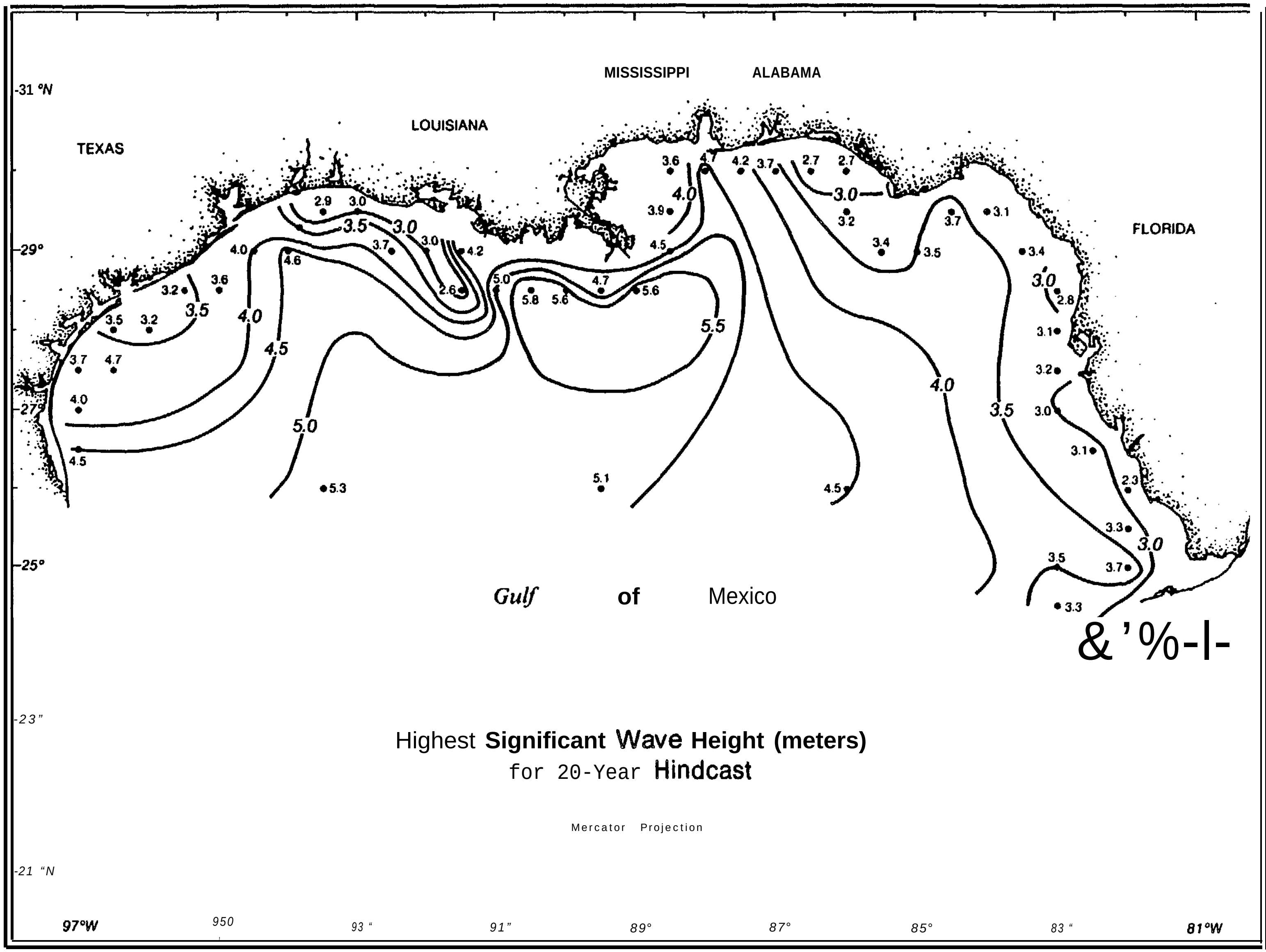


Figure 11-14. Highest Significant Wave Height (meters) for 20-Year Hindcast.

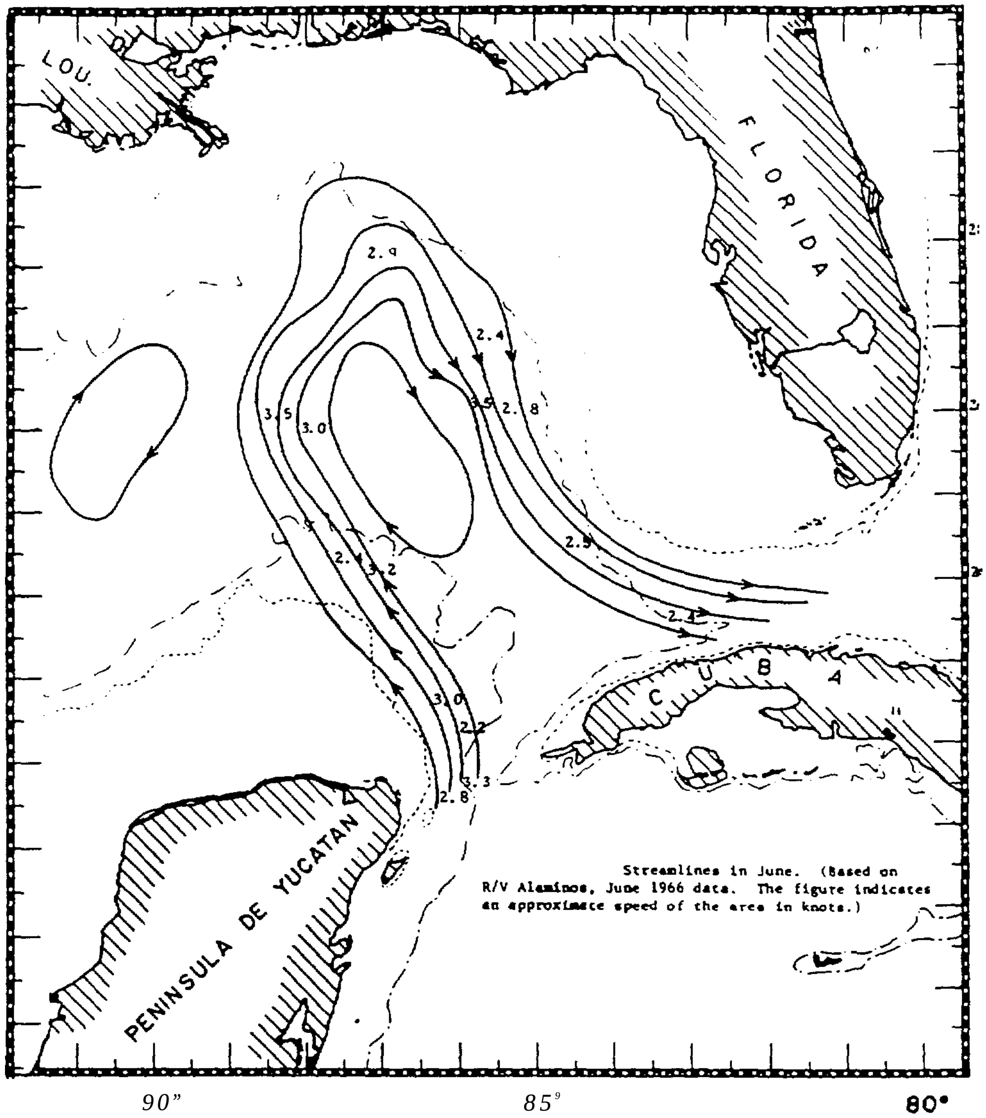


Figure 11-15. **The Loop Current (from Ichiye et al. 1973).**

FIGURE II-16. Surface currents, Straits of Florida.

western Gulf, winds, waves, and water column density. The shelf circulation, particularly in the northwestern Gulf, shows strong influence from secondary flows of the Loop Current. Surface circulation is affected more by tides, winds, and freshwater inflow than by the open Gulf circulation features. The mean seasonal circulation is better known for the Texas-Louisiana shelf than for the eastern Gulf. Figure F-4 shows streamlines of the mean flow on the Texas shelf, computed from historical data (Cochrane and Kelly, 1986). The spacing between the streamlines is proportional to the magnitude of the mean surface currents. In months other than June, July and August, an elongated region of counter clockwise circulation dominates the shelf. On the inner shelf side, flow towards Mexico prevails, which is driven by the mean wind field that has an easterly component during months other than June, July and August. The coastal flow carries the discharge from the Mississippi and Atchafalaya Rivers and a large load of suspended sediments far down the Texas coast. Along the outer shelf and shelf-break there is a counter flow towards the east.

Historic sailing routes suggest that navigators became aware of the predominantly easterly flow along the outer shelf and took advantage of it when sailing from Veracruz to the eastern Gulf, as they could pick up at least 25 cm/s (0.5 knots) of speed. During the summer months, the coastal currents reverse, flowing northward along the lower Texas coast and eastward along the upper Texas and Louisiana coasts to Calcasieu Pass, Louisiana. Eastward flow on the outer shelf is weaker during the summer. The flow offshore of the Florida shelf is dominated by the southward flowing side of the Loop Current. It is so strong (1 02.8 to 154.2 cm/s) that it was immediately noted by the first explorers.

Blumberg and Mellor (1981) describe the typical wind field for the Gulf of Mexico. The northwestern Gulf is dominated by the easterly trades which vary from a southwesterly flow in summer to a northeasterly direction in winter. Major perturbations in this wind regime occur during winter with the passage of rapidly moving cold fronts termed "northers" (McGrail and Carries 1983). DiMego, et.al (1976) analyzed all frontal passages into the Gulf for the period 1965 to 1972 and computed statistics of frequency and duration of frontal systems. Table F-2 shows the results for the middle of the Texas-Louisiana shelf as interpolated from their maps. The transition from the low frequency regime of summer to the high frequency regime of winter occurs between September and October.

Waves associated with the winds of the Gulf are generally only 1-1.5 m in height with 5-6 second periods over much of the year. Winds associated with cold fronts frequently produce three to four meter wave heights, while midwinter fronts can raise waves to seven meters (McGrail and Carries 1983). These rare waves represent a low percentage of the general distribution for the Gulf as seen in Figure II-14. That they occur and can wreck large sailing vessels such as the SAN MIGUEL suggests an important role for storm related waves in the cause of historic shipwrecks. Figures F-5a and II-14 show the mean significant wave height and highest significant wave height, respectively, for northern Gulf waters based on hindcasts of 20 years of wave statistics (Hubertz, et.al. 1988). Tropical storm and hurricane conditions were specifically excluded from the wind fields used for the hindcast. Significant wave height is the average of the wave heights of the highest one-third of the waves in a wave record. Significant wave height is statistically related to other wave height estimates. The average of the highest ten percent of the waves in a record is equal to 1.27 times the significant wave height, and the average of the highest one percent of the waves is equal to 1.67 times the significant wave height. Figure F-5 suggests that mean significant wave heights are slightly higher east of Cape San Bias, over DeSoto Canyon, and along the south Texas coast. The latter may be a result of wave and current interaction between southward flowing coastal currents and northwestward moving waves that are driven by the mean winds. Figure II-14 suggests that the region west of the tip of the Mississippi Delta is a high energy zone under storm conditions. In general, for offshore Gulf waters, storm waves exceeding 6 m can be generated by storms.

Andrews (1978) describes the effects of the wind and current system in the Caribbean and the Gulf of Mexico, Westward tradewinds blow steadily for most of the year. The powerful, east-flowing currents that form the Gulf Stream add to the natural forces affecting sailing or navigation from the 16th to 20th centuries. Favorable conditions made for swift east-west voyages from Spain and across the Caribbean. An example in the 16th century was a 20 day cruise that covered 2400 km from Dominica to Cape San Antonio (Andrews 1978). Above the Florida Straits more favorable voyages could be made for west to east trips in concert with the Loop Current (Hoffman 1980).

"Northers" as a wind-related factor in shipwrecks, are second in importance only to hurricanes. "Nortes" are mentioned due to their impact on Spanish fleets as early as 1566 where Captain General Pedrode de las Roelas gives an account of his ships requiring 55 days to reach Havana from San Juan de Ulua after being dispersed by a norther on April 5 (Chaunu and Chaunu 1955)

The influence of these fronts is seen where storms caused the loss of three galleons of a Spanish treasure fleet in 1551. Struck by "storms" in March, the fleet was dispersed and one galleon, the SAN MIGUEL, was extensively damaged. When attempting to reach Havana, it was blown into the Straits of Florida by a south-southwest wind and forced to enter the Bahama Channel without landing in Cuba. With a "wind contrary for La Habana (Havana) and good for Spain", the galleon began her run for Spain. No sooner had she begun when the wind turned into the east again and the vessel found itself dangerously near the "Los Martires" (Florida Keys). Winds turned so sharply south to east that the galleon was battered for three days and nights until it was demasted, became rudderless and ran aground on 29 April (Chamberlain 1988).

Tropical storm and hurricane winds create the most extreme wave and current conditions in the Gulf that not only cause shipwrecks but also affect the remains of shipwrecks, Abel (198$) hindcast wave statistics for 20 years. Although 20 years is a relatively small sample, their computed results for 20 year and 50 year external waves (Figure F-6) for 56 locations around the Gulf (Figure F-7) are useful in assessing factors such as energy zones and preservation. As with normal wave conditions, the regions of the lower Texas coast and the Mississippi Delta are relatively high energy zones.

7.0 HURRICANE PATHS

7.1 Historic Perspective

Shipwreck locations predetermined by, but not caused by, sailing routes and ports. On the other hand, seasonal hurricanes do cause maritime losses. Hurricane, derived from the Caribe Indian word "ouragan," entered English as "hurricane" (Millás 1968). The pre-Columbian Indians knew the destructive power of these storms. Early navigators learned by experience. Columbus experienced hurricanes as early as his second voyage on June 16, 1494 (Henry, et.al. 1975). The Spanish learned to schedule their fleet sailings around the peak season. Large fleets that sailed against these storms were lost in the Keys and Bahama Channels during 1622, 1633, 1715, and 1722.

The French and British were aware of the force of hurricanes from reports of destruction along the northern Gulf (McWilliams 1981; Ware 1982). The effects of these storms fell equally upon them all with only the number of maritime losses being mitigated by the differences in the number of vessels of the respective colonial powers at any one time. Spanish shipping, the most numerous in the early centuries, sustained the greatest number of losses. With ports along the entire northern shore of the Gulf by the mid-19th century, there were few areas where maritime commerce could not be impacted.

7.2 Storm Paths and Shipwrecks

Fortunately for mariners, the natural frequency of hurricanes is statistically low. Approximately 7.5 storms form per year mostly during August, September and October. Sixty-three years of hurricane data indicate an average occurrence of one hurricane per year for the area of 25-30° latitude which includes the Gulf of Mexico (Hayes 1967). One hundred years of data for Texas supports this estimate of frequency (Henry et.al. 1975; Tannehill 1956).

Modern forecasting terminology refers to "strike probability" as the most likely point for a hurricane's landfall. This study considered historic hurricane tracks and correlations with shipwrecks. Estimates of severe storm occurrence can be made for segments of the Gulf coast, but it is difficult to determine the tracks of hurricanes (Dewald 1980). The reasons for this are: (1) lack of extensive historical data on storm tracks before the modern era of weather aircraft and satellites; and (2) inherent randomness in individual storm tracks. Appendix F shows the variability of individual hurricanes. The only observable tendency is for the greater storms to move erratically westward for many days before recurving in parabolas of varying pitch (Mason 1972). This observation may be only an artifact for the data acquired the last 50 years.

Millás (1 968), in his extensive study of historical hurricanes between 1492-1800, underscores the importance of shipwrecks related to tropical storms. The most important elements in the relationship of hurricanes, shipwrecks, and the natural or historical factors are: (1) reported shipwreck frequency; (2) seasonality; (3) historic period; and (4) development of ports and trade routes. When there was relatively low shipping, shipwrecks are rarely observed in the historical literature. As the frequency of shipping grew and routes dispersed over the circum-Gulf area, the interplay of a normal storm frequency guaranteed a higher incidence of vessel losses. Variation enters into this scheme due to stochastic variations in storm frequency.

A composite representation of tropical storm tracks shown in Appendix F does not show any patterns. The 755 storm paths cover the Gulf of Mexico (Gleick 1987). A general trend shows paths that follow the tradewind belts but there is little predictable behavior beyond this observation (Dewald 1980).

It is difficult to examine the complete path of a historic hurricane and the incidence of shipwrecks along it. Where such data are available, it is primarily post 1830 (BLM Visual No.

2; Tannehill 1956). While it gives insight into modern losses from storms, the extrapolation to historic storms seems tenuous. As good as the data presented by Millás (1968) on storms of the Spanish period are, historic paths can only be speculated.

Recognizing these methodological problems, we analyzed documented cases such as the 1722, 1733, 1778, and 1780 storms in the Colonial era, selected storms from 1916-1981 and a suite of recent data from 1945-1977. The results are shown in Tables II-5 and II-15. Hurricane Juan, a relatively weak, late season Gulf hurricane, is presented due to the extraordinary data obtained by the R/V PELICAN trapped in the storm's path for several days in 1985 (Figure 11-1 7) and compared to that of SOLANO'S FLEET in **1780 (Appendix** F; SAI 1985; Millás 1968; Tannehill 1956).

This is not an exhaustive accounting of the losses caused by storms over the historic and modern eras. It is a sample of the data that exists from diverse sources. The data does support the expectation that given the incidence of a major tropical storm in the northern Gulf, we can assume an increased frequency of shipwrecks for any one year. With an overall frequency of one hurricane per year for the Gulf region, any intersection of that storm with principal shipping routes or ports may result in an increased number of vessels lost. If it is a large hurricane, then the probability of vessels being lost is almost certain. The pattern of shipwrecks will then be expected to follow shipping routes rather than some general trend of historic hurricane paths. Given the random pattern for storm tracks, their chance intersection with fixed shipping routes is important in the explanation of observed shipwreck patterns.

Tables II-5, II-6, II-7, II-8 and II-9 present reported vessel losses correlated with specific storm paths. The hurricanes selected are documented in various historic and modern sources and allow a qualitative correlation between path and number of vessels lost. The years selected show a marked increase in percentage of vessels lost per year to hurricanes compared to the observed average for the 21 year' MVUS sample. For example, the MVUS sample for 1961 shows a 16 percent loss while our calculated data indicates a 35 percent loss due to storms (Table II-5). Table II-10 compares large hurricanes and shipwreck occurrence. The expected relationship between "super" storms and shipwrecks is mitigated by the observed frequency of losses in the areas of zero probability for these storms. (Table II-1 Oa). Central and eastern ports of the northern Gulf where the frequency of great hurricanes is low, show a relatively even density of shipwrecks similar to the central and western areas (Table II-1 Oh). Given the few number of major ports in the eastern Gulf this frequency can be largely explained by the location of Gulf shipping lanes and the continued impact of lesser size storms than great ones. Table II-11 presents basic data for hurricane frequency by state, and Table 11-12 shows calculations of shipwreck frequency in Gulf areas.

Table II-1 3 compares tropical storm probability and shipwreck occurrence. A strong correlation between hurricanes and shipwrecks is not supported by the data presented in these tables. Storms, hurricanes, northers or squalls did increase the frequency of shipwrecks but not to a degree that one can point to an area of increased storm frequency and observe a corresponding increase in shipwrecks. Storms act only in concert with other variables such as port location and shipping routes. When these factors converge, an increased frequency can be seen. This observation is supported by analyses presented later in this report.

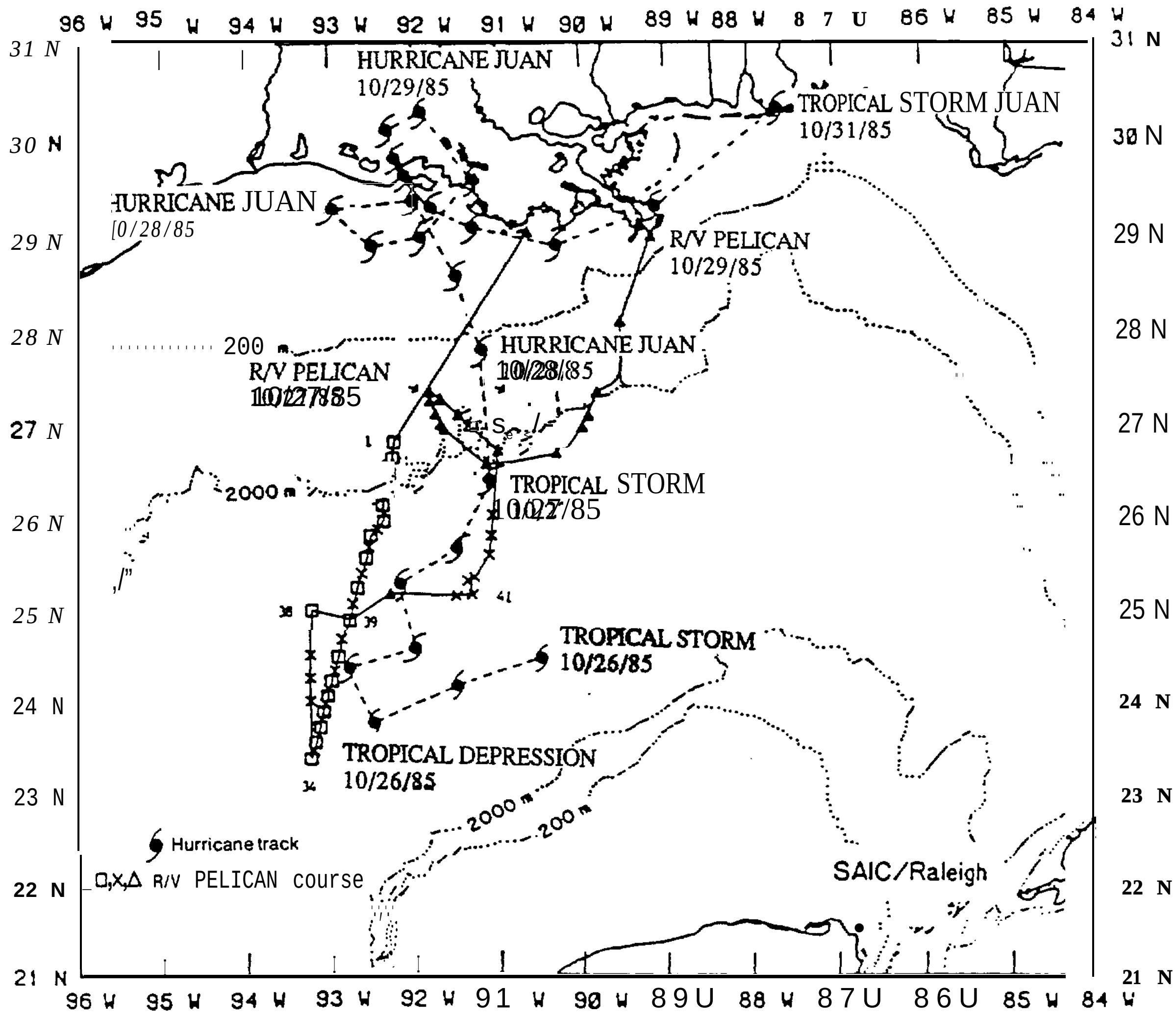


Figure II-17. Cruise track of R/V PELICAN and path of Hurricane Juan, Oct. 1985 (from SAIC 1988).

Table II-5

HURRICANE AND NORTHER-RELATED LOSSES FOR SELECTED YEARS, MVUS DATA

Year	Total Losses	Total Reported as Hurricane Losses	Total Reported as Other Losses
1945	1	o	o
1946,1947”	7	0	0
1947,1948*	2	0	0
1957	1	1	0
1958	2	0	0
1959	2	0	1
1960	23	5	2
1961,1962*	28	10	0
1962	-		-
1964	2	0	0
1965	4	2	0
1966	6	0	0
1967	23	6	1
1968,1969”	21	1	0
1969	31	8	2
1970	10	1	1
1971	19	0	1
1972,1973’	33	5	1
1973,1974”	21	0	0
1974	77	1	0
1975,1976”	28	2	0
1976,1977’	77	Q	Q
	286(100%)	47(16%)	9(3%)

*Several reporting periods (MVUS) included in single volume year

Table II-6.

HISTORICAL REPORTS OF GULF HURRICANES; SPANISH DATA.

YEAR	LOCATION	VESSEL LOSSES	SOURCE
1551 (Nov)	S.E. Gulf; Straits of Florida	at least 4 lost (1 urea)	Spain, Documents de Ultramar, 1864, Serie 1, V Millás, 1968
1551	S.E. Gulf Straits of Florida	none mentioned	Anales de la cademia d? Ciencas de la Habana, Vol VII, p. 330; Millás 1968
1554	S. Coast of Florida	3 (stranded on coast)	Spain 1864, Documents de Ultramar, Serie II, XIV, 25 Millás, 1968
1559	**Pensacola Bay**	7 vessels destroyed	Priestly, 1971
1568	**Florida**	none lost	Richard Hakluyt, Spanish Documents concerning English voyages to the Caribbean Sea, 1527-1568, Document Nos: 26, 27, and 28, MillAs, 1968
1622	Florida Straits	La Margarita (Galleon) at Matacumbe Key: Nuestra Senora de ocha Rosario at Tortuga; a Frigate and 3 ships	Pezuela, Jacob de 1842 Ensayo historico sobre le Isla de Cuba New York, Millás, 1968
1623 (Sept/	Florida Straits	Flagship (almiranta) and the galleon Espiritu anto	Documents Ineditos de Indias Spain, 1864, II 14, 43, Duro, 1895, iv, Millás, 1968

Table II-6
(continued).

1634 (Sept)	Straits of Florida	flagship and 2 other ships on keys of Matacumbe	Duro, 1895, iv, 451 Millás, 1968
1641 (Sept)	Straits of Florida	none in Gulf	Duro, 1895, iv, 449, Millás, 1968
1644	Straits of Florida	10 English vessels, Keys	Lopez de Cugolludo, 1688, Millás 1968
1692 (Ott 24)	Florida	none	Millás, 1968
1695	Florida Keys	Winchester 4th rate near Key Largo (not Gulf of Mexico)	Millás, 1968
1715	Straits of Florida in Bahama Channel	10 vessels lost Millas, 1968	Duro, 1900, vi, 121, 489
1724	Gulf of Mexico	Navies de azoque Guadalupe and Tolosa lost with all hands	Duro 1900, vi, 489, Millás 1968
1720	Straits of Florida	2 vessels in Keys	Duro, 1900, vi, 489, Millás 1968
1733	Straits of Florida	La Florida at Matacumbe Key; flagships and 6 ships at Viboras Key, 2 in Key Large; 2 in Matacumbe Key; 2 in the small key of Matanzas; 1 in key vaca, 2 in Los Mártires	Duro, 1960, 489 Millás, 1968
1766	Pensacola	Fleet wrecked; Le Constance lost on Chandeleurs	Tannehill, 1956; Pearson 1981
1780	Straits of Florida S.E. Gulf of Mexico to Miss. River (N.E. half of Gulf of Mexico (formed in Gulf)) Ott 20: 100 miles SSE of Miss. R. delta	19 ships lost * near 25°27N 91°7W, 26"42N 86°11W	Admiral Jose Solano marqués del Socorro Millás, 1968; Tannehill 1956

* locations coincide with similiar storm Ott 21

Table II-7

HISTORICAL REPORTS ON GULF HURRICANES; FRENCH DATA

YEAR	LOCATION	VESSEL LOSSES	SOURCE
1722	la Louisiane	several small craft (chaloupes)	A. N., C., Ser C^{13}, vol. vi, fol. 340
1732 (Aug)	la Louisiane	Spanish frigate at Chandeleurs; Vigilante	A. N., C., Sér. C^{13}, vol. xvi, fols. 7 (Feb. 5, 1733)
1734	Mobile (New Orleans-Mobile)	none-severe storm in April 1 ship off Island (many others destroyed)	A. N., C., Sér C^{13}, vol xvii, fols 53-54
1735	off Havana; S.E. Gulf of Mexico	2 vessels (French) before the end of the year... hurricane	A.B.N. Fr., vol. 10769, fol. 88
1738	la Louisiane	**4 ships wrecked by storms (hurricanes) 202-203, 221**	A. N.,C., Sér. C^{13} vol xxii fols. 221
1740 (Sept)	la Louisiane Mobile-New Orleans	**large bateau lost, boats of all kinds**	A. N., C., Ser. C^{13}. vol xxvi, fols. 127-130
1750	la Louisiane	**large storm at** harvest (29 Sept 1 750)	A. N., C., Sér. C^{13} xxxiv, fol. 347
1752	la Louisiane	numerous storms and hurricanes - in fall harvests	A. N., C., Sér. C^{13} vol. xxxvi, fols 228, 271
1755	mouth of Miss. River	1 vessel destroyed by storm (hurricane)	A. N., C., Sér. C^{13} vol. xxxix, fol.

Table II-8.

CORRELATION OF HURRICANE DATA FROM SPANISH AND FRENCH SOURCES.

YEAR	SPANISH	FRENCH	COMMENTS
1722	Sept 819, Jamaica Grand Cayman	lower Louisiana Coast, New Orleans, "everything in port lost"	storm moved WNW Jamaica over Caymans and probably over Yucatan Channel into the Gulf of Mexico (Millás 1968: 178)
1732	no record	Chandeleur Islands, Mobile	Storm probably formed in Gulf of Mexico due to lack of reports from Spanish, sources in West Indies (A. N., C., Sér. C1 3A, vol. xvi, fol. 7)
1734	no record	April; Mobile	
1734	Sept 12, Jamaica	fall(?)	Storm came from south-eastern Caribbean Sea, Moving WNW after crossing Jamaica (Minds, 1968: 19)
1735	no record	2 vessels between Cuba and Louisiana, before the end of the year	Gulf hurricane? Reference: A.B. N.,Fr. vol. 10769, fol. 88
1738	(2) Aug 30, Puerto Rico South Hispanola (2) Sept 12, Guadaloupe, St. Thomas, Puerto Rica, Santa Domingo	Louisiana no date	(Mobile-Storm (1) moved due west after striking New Orleans) southern part of Hispanola (2) changed directions several times originating in

Table II-8
(continued).

			Atlantic east of Guadaloupe Caribbean, moved N.W. passed south of Virgin Islands thence WSW-W crossing south coasts of Puerto Rica and Hispanola
1740	Sept. 1 1/12, **Puerto** Rico	**9/1 1/18; Mobile** New Orleans Pensacola	moved S. E.; normal to weak intensity
1750	**no** storms reported	Sept. 29, Louisiana (Mobile-New Orleans)	Gulf hurricane "large storm" A. N., C., Sér.C13, vol xxxiv, fol. 547
1752	no storms reported	Louisiana "harvest (fall ?)"	Gulf tropical storms or hurricanes? Two storms in September Tannehill 1956 A. N., C., Sér C13, fols. 220,271
1755	November, Cuba (3)	mouth of Miss. River date unknown	Gulf origin
1766 *	Ott 8, Puerto Rico	Pensacola, Ott **22**	**Perhaps-there is too much separation in dates to be same hurricane. Hurricane at Pensacola may have had** a Gulf origin and minimal strength Ref. Gauld in Ware 1982:78, Still this may be the same

Table II-8
(continued).

			hurricane as at Puerto Rico.
1780 *	Oct. 20/21 Gulf of Mexico, approx, 26 N Latitude, 86 W Longitude. Landfall west Florida (Pensacola)	a) Aug 24, 1780 (4) landfall at Miss. River delta-Pensacola b) no association	Storms of Gulf origin (Millás, 1968: 260-2 Tannehill, 1956 reports four October hurricanes,

• After 1763, French possessions ceded to Britain in settlement of Seven Years War. Data for 1 766 from British sources.

Table II-9.

HURRICANE-RELATED **LOSSES FOR SELECTED HISTORIC STORM PATHS.**

YEAR	PATH OF HURRICANE	LOSSES	SOURCES
1722	Jamaica, Grand Cayman, W. Cuba Yucatan Strait to Mississippi Sound	several "chalaupes"	MillAs; A. N., C., Sér. C[13]
1733	S.E. Gulf, Florida Strait, Bahama Channel	19 vessels	Millás; Florida (Bureau of Archaeological Research)
1766	Gulf?, Pensacola	"Spanish fleet wrecked"	Tannehill (1956: 245)
1778	Jamaica, Yucatan Strait, to Pensacola	17 vessels	Florida (Bureau of Archaeological Research)
1780	26°42'N, 86°11 'W to 25°27N, 91 °7'W to Matagorda Bay, TX	19 vessels	Millás (1968)
1846	Caribbean, Havana, Key West, Apalachicola area	20 vessels	Tannehill (1956)
1893	Caribbean, Yucatan, Delta, Mobile	"fishing fleets destroyed"	Mistovich, Knight and Solis (1983)
1916	Yucatan Strait/W. Cuba(?) to Pensacola	16 vessels; "30-40 boat's destroyed in Biloxi-Gulfport region"	MVUS (1916); Mistovich (1 987)
1919	18"N, 63°W; Puerto Rico, Tortugas, S. Texas	10 vessels	Tannehill (1956)
1960	Old Bahama Channel, Straits of Florida, Cape Sable	5 vessels	MVUS; Visual No. 2
1961	Caribbean, Yucatan Channel West Gulf, Matagorda Bay	10 vessels	MVUS; Visual No. 2
1967	Yucatan, Bay of Campeche, Rio Grande	6 vessels	MVUS; Visual No. 2
1969	Caribbean, W. Cuba, S.E. Gulf Mississippi Sound	8 vessels	MVUS; Visual No. 2

Table II-9
(continued),

1972	Yucatan Channel, E. Central Gulf; Cape San Bias	5 vessels	MVUS; Visual No. 2
1981	Origin of Frederic's Track, E. Central Gulf, Dauphin Island - Gulf Shores, AL.	11 vessels	MVUS

Table 11-10a.

SHIPWRECK VERSUS "GREAT" HURRICANE PROBABILITY IN THE STUDY AREA.

Coastal Sectors of Zero Probability for Great Hurricanes*	Shipwrecks per 1° of Latitude-Longitude centered on Coastal Sectors of **Zero Probability** **
9	141
10	211
14	143
15	84
16	75
17	72
18	30
19	3
20	96

* After Simpson and Lawrence 1971; cf. Figure 3. That study.

•* Data,- this study

Table II-10b.

INCIDENCE OF MODERN "GREAT" HURRICANES IN GULF (AFTER TANNEHILL, 1956).

1886	Apalachicola, Florida (June)
1886	Indianola, Texas (August)
1900	Galveston, Texas (September)
1906	Alabama (September)
1910	Key West (October)
1915	Galveston, Texas (September)
1916	Corpus Christi/Brownsville, Texas (August)
1916	Mobile/Pensacola (July)
1919	Key West/Corpus Christi (September)
1929	Panama City, Florida (September)
1933	Brownsville, Texas (September)
1947	New Orleans, Louisiana (September)
1957	Calcasieu Parish, Louisiana (June)
1961	Port O'Conner, Texas (September)
1969	Biloxi, Mississippi (August)

Table II-11

HURRICANE FREQUENCY BY STATE, 1879-1943 (AFTER MITCHELL, 1924 AND TANNEHILL, 1956)

State	Frequency per 100 miles of Coastline
Texas	9.5
Louisiana	4.5
Mississippi	15.4
Alabama	13.2
Florida	4.4

Table II-12

VALUES USED TO CALCULATE SHIPWRECK DENSITY

Lat./Lena.	Gulf Areas	Area(mi.^{2})	n	n/A
24-26°/97-960	Rio Grande	3600	154	0.04
26-28°/97-960	Western	7200	590	0.082
28-29°/93-960	Central	14,950	1308	0.088
27 °30’-300/93-890	Central La.	28,400	728	0.026
30 °-27030’/ 89-880	Miss./Ala.	10,800	284	0.026
30°-280/880-850	West Florida	14,400	210	0.015
30°-280/86-830	Big Bend	14,400	278	0.019
29-27°/84-820	Middle Ground	7,200	271	0.038
27-25°/84-810	SW Florida	18,000	175	0.01
24-25°/83-800	Tortugas	10,800	818	0.076
	Total	129,750	4816*	0.0371

• number includes duplicate entries

Table II-13.

SHIPWRECK VERSUS HURRICANE FREQUENCY IN THE STUDY AREA.

Tropical Storm Probability/ 50 Mile Sector*	Historic Shipwreck Frequency/ 0 Latitucie-Lena itude**
4%	97
5 %	26
6%	114
7%	176
8%	126
9%	270
1270	335
13%	84
14%	52

● 13atafrom Simpson and Lawrence 1971; cf. Fig. 3. That report.

● *Data from Shipwreck File, this report.

8.0 SEDIMENTS, ENERGY ZONES AND OTHER PRESERVATION FACTORS

> "In general, given similar bottom conditions, it appears that the breakdown and deterioration of vessels of wooden and composite construction lost in reasonably calm areas on a bottom composed of silts, sand, or a combination of these materials will be similar whether the water is 10 m or 100 m deep and the wreck 20 or 2,000 years old (CEI 1977)."

This quote, offered as a summary statement in the 1977 report by CEI, while presenting a generally broad treatment of the relationship of historic shipwreck preservation, sediments and energy zones, is more correctly, a hypothesis concerning these variables. It provides little predictive value regarding shipwreck materials, nor are the relationships of these factors discussed. The preservation of shipwreck materials in the marine environment includes the interaction of shipwreck material, sediment type, sediment depth, energy, water depth, water temperature, water column chemistry, and biological activity.

A recent example of the acceptance of untested assumptions concerning historic shipwreck preservation is that of the RMS TITANIC. The discovery of the lost superliner by a joint French-American expedition in 1985 was one of the most dramatic events in the past decade. One observation was repeated with a tone of disbelief: the total absence of preserved wood on the wreck. It was assumed that the preservation of organic materials, such as wood, was enhanced in deep, cold marine waters **(Marx 1971).** The principal reason for this expectation was assumed low levels of biological activity by organisms such as marine borers whose range did not include the deep ocean. This observation about the shipworm *Teredo*, common to warm ocean waters, was correct. Not taken into account was the presence of other marine boring organisms. Further, expectations about metal preservation, particularly iron, were also in error. Marine bacteria have reduced the great ship to a rust hulk. Only the great mass of the wreck prevented more complete destruction of the hull and superstructure. Expected redox rates due to low temperatures did not prevent the deterioration of ferrous materials by biological and chemical factors. Some of the more general expectations concerning preservation in deep water shipwreck archaeology were changed by discoveries made on the TITANIC. This being the case with the dark, relatively static abyssal zone of ocean we should expect less for the shallow, more dynamic continental shelf and slope of the northern Gulf of Mexico.

Brown (1987) reported on controlled *in situ* experiments utilizing timbers and ferrous materials of historic shipwrecks where differential deterioration processes were measured relative to marine biological and chemical processes. Shipwrecks occurring in shallow coastal waters of the Gulf can act as artificial reef structures where recruitment and colonialization of the wreck fabric is immediate and thorough. While encrustation occurs on the wreck exterior, destruction internally proceeds as *Teredo* worms infest the wreck. In a short time, a timber is deteriorated from the inside although it seems preserved in the sediments. The key element in estimating preservation of wooden shipwreck material is the identification of the burial sediment, its depth, and the inherent biological communities associated with such conditions.

The survival of shipwreck materials has been discussed by Clausen 1965; Gluckman 1967; Mathewson 1975, 1977; Muckelroy 1978; Burgess and Clausen 1976; Dethlefsen 1978; Marx 1985; Watts 1985; SAI 1981; Keith, et. al. 1985; Smith 1985; and Keith and Simmons 1986. Wrecks range from 16th century caravel vessels to the Civil War ship, USS MONITOR. The principal cause for the wreck of most vessels was shallow reef or sandy shoal areas. The exception is the MONITOR which lies in water over 70 **m.** The MONITOR is a metal vessel and the others are wooden sailing craft, With the exception of the MONITOR, none of the vessels were found intact.

The destruction of the wooden hulls by grounding in a high energy wave zone together with subsequent deterioration over time have combined to preserve little of the ship's fabric in many of the case studies. A few ship frames, floors or fragments of scantlings leave mainly a scatter of differentially preserved artifacts about a ballast feature. The vessel reaches an equilibrium with environmental factors. Depth appears to be a factor but only in relation to water chemistry. Wave related destruction is ameliorated or retarded by either protection from exposed features such as ballast or by simply being reduced to such a configuration as to preclude further erosion. Where wave or currents of any magnitude cannot act strongly on a hull such as the MONITOR, or an extreme case, such as the TITANIC, the vessel survives as a more or less recognizable reflection of the original ship. This observation is corroborated by observations such as those made on the BREADALBANE (MacInnis 1985) where depth and cold have preserved this wooden vessel, and with the USS HATTERAS (Arnold and Hudson 1981) of the Civil War period.

The relationship of sediments to the preservation of a historic shipwreck site appears related to physical protection from erosional forces. Muckelroy (1977, 1978) suggests that waves and currents break up and carry away more of a ship than biological or chemical destruction.

The best guarantee for preservation of all types of material in either shallow or deep water is for everything to be buried by sediments, especially if the sediments are low in oxygen, e.g. a chemically reducing environment. The process of burial is generally more rapid in nearshore waters where sediments are transported by longshore and storm currents. The nearshore sediments of the northern Gulf are typically coarse with silt and clay muds farther offshore or on the slope of the shelf proper (Figure 11-18).

The importance of sediment transport and subsequent burial probably explains the good preservation of wrecks including the SAN JOSE, EL LERRI (Smith 1978) and the Molasses Reef Wreck (Keith and Simmons 1985). Vessels in dynamic, biologically active areas like the shoals and reefs of the northern Florida Straits and Bahama Channel that remain preserved seem to have fallen into natural lacunae where sediments buried their remaining fabric.

Where sediments cannot quickly bury the wreck, ballast seems to be the only means for preservation of any hull or cargo remains in the nearshore environment. Preservation in the open sea must rely on factors other than burial as sedimentation rates (ea. 0.012 m/year) are very low. Those elements buried in the muds shared the greatest chance of survival as evidenced by the remains of the EL NUEVO CONSTANTE (Pearson, et. al. 1981). Bascom (1971) and Muckelroy (1 978) speculated on factors operating in the deeper water that could aid in preservation such as lower temperatures and oxygen, and slow corrosion rates, especially of ferric metals. Currents promote erosion by mechanical or chemical means. Recent research results on the deepest of known shipwrecks, the RMS TITANIC, show extensive destruction of wooden materials by organisms (Ryan 1987). While *Toredo* and *Limnoria* do not live below 100 m, other organisms such as *Xylophaga* and *Xyloredo* (Ryan 1987) do.

8.1 Sediments of the Gulf of Mexico--General Background

Berg (1986) characterized the Holocene sediment distribution of the northern Gulf of Mexico continental shelf as follows:

Litoral (beach)	longshore sands, silts, clays
Ncritic shelf)	alternating muds, sands overlying Pleistocene clays
Bathyl (slope)	sand and shell banks, muds, clays
Deltas	foreset beds of sands, silts, muds organics

This general surface sediment distribution for the northern Gulf of Mexico is shown in Figure 11-18. Berryhill and Trippet (1981) state the Holocene sediments of 96"W longitude range from 4 to 43 m in thickness. These sediments begin thinning east of 96"W longitude. From 96° to 93"W a veneer or lack of Holocene sediments is seen (Brashier, Beckert and Rouse

1983). Those sediments east of this general area are known to have up to 15 m of sandy sediments (Nelson and Bray 1970; Kolb and Van Lopik 1958).

East and north of the Mississippi delta, sand and shell make up most of the surface sediments (Scruton 1960). The shelf sediments east of the delta to DeSoto Canyon are dominated by the MAFLA sand sheet (Berg 1986; Alexander 1978). Terrigenous sediment, containing varying amounts of silt and clay occur off Mississippi and Alabama (Rezak, et. al. 1985). Southeast of the Apalachee Bay is a karstic shelf of thin or no sediments on the outer shelf. (Berg 1986; Alexander 1978). Sands occur shoreward and give rise to headlands like Cape San Bias and shoal areas like the Marquesas and Tortugas. Slope sediments on the eastern shelf are generally thin (≤1 m) overlying the karstic Florida platform. Muds are seen to be thicker in the Desoto Canyon portion of the slope. These latter observations were made on the 1985 cruises of the OREGON II and JOHNSON SEALINK. Overall sediment thickness deposited during the last 10,000 years averages about 23 m and yields a low sedimentation rate of 0.012 m/yr. Major sediment sources for the northern Gulf shelf are the Mississippi and Rio Grande rivers (van Andel 1960).

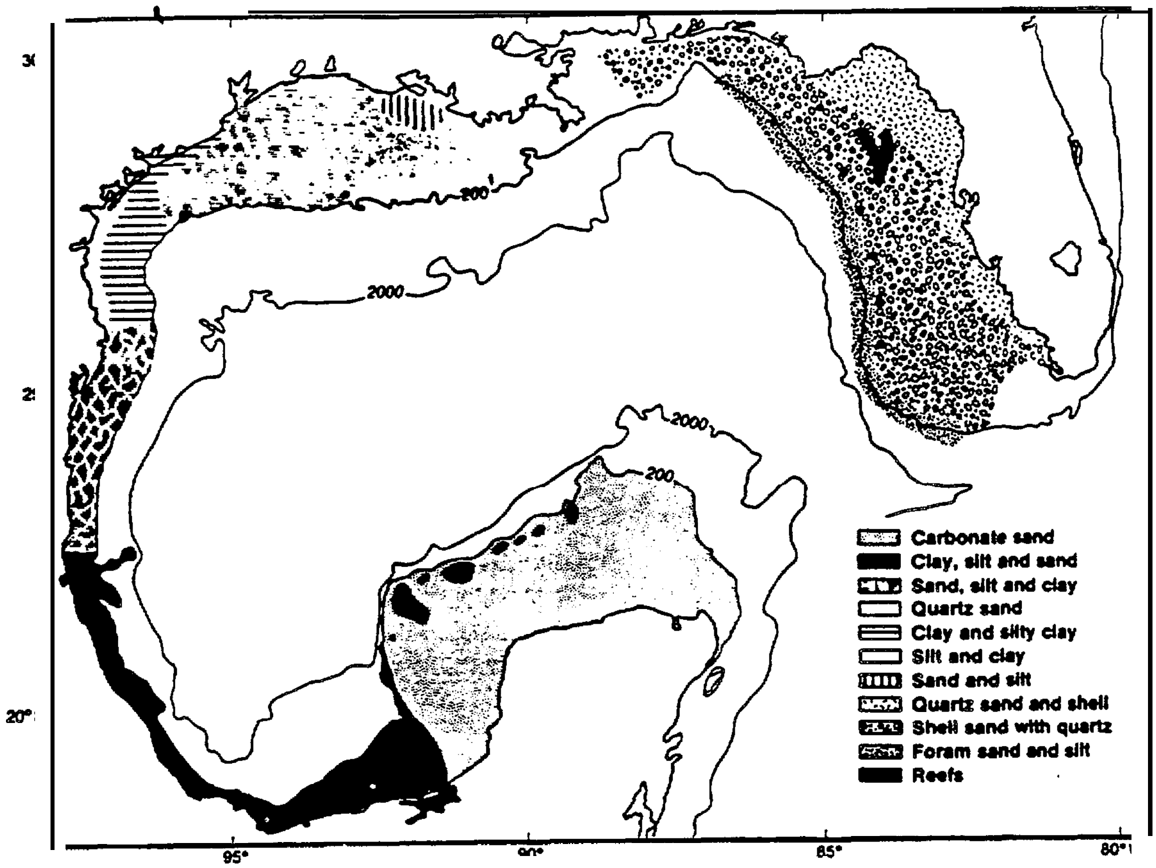


FIGURE II-18. Sediment distribution, Gulf of Mexico Outer Continental Shelf (from Rezak *et* al., 1985).

8.1.1 Energy Zones

The energy zones measuredly wave height and current velocity follow the wind flow of the Gulf (Blumberg and Mellor 1981). Westerly winds dominate the surface circulation and create a moderate-high energy zone along the central-lower Texas coast. The upper Texas to western Louisiana coast grades to a low energy zone (average wave height < l m). Eastward of the Mississippi delta, the Mississippi-Alabama-Florida shore is a moderate-low energy zone. The peninsular coastline of Florida progrades with mangrove swamps and convex barrier islands indicative of a low energy regime (Curray 1960; Tanner 1985) (Figure II-19).

Surf zone energy levels range from zero (< 4 cm) to moderate. The best example of the zero energy coast in Florida is the “Big Bend” coast between Tallahassee and Tampa (Tanner 1985). The zero to low energy coast condition occurs because: (a) prevailing winds blow from land to sea; (b) coastline concavity provides divergence of wave orthogonal and reduces wave energy to the coast; (c) the offshore coast is shallow and wide so deep water wave energy is dissipated in frictional processes crossing the shelf; and (d) the Gulf does not produce the upper parts of the typical ocean spectrum of periods and heights (Tanner 1985).

The western Louisiana and eastern Texas coast are concave with a broad shallow shelf that creates a low energy coastline (Kwon 1969). Moderate to high energy coasts occur in conjunction with barrier islands along Mississippi, Alabama, and Louisiana.

8.1.2 Biological *and Chemical Factors*

The wrecking process and decomposition rates involved in shipwreck preservation have not been extensively studied and are poorly understood. Factors such as energy zones, biology, and chemistry interact dynamically and vary with the environment. This section reviews known factors in shipwreck decomposition. The effects of biological organisms that attack organic materials during and after the mechanical breakup of a ship are examined. These organisms are chiefly bacteria and shipworms. We also examine the decomposition of metallic materials as a result of electrochemical activity and relate the deterioration of materials to sediments and energy zones.

8.1.2.1 Borers and Bacteria

The recent rediscovery of the RMS TITANIC provided new insights into the breakdown of a large shipwreck by marine organisms (Ryan 1986; Ryan 1987). Lying more than three kilometers in the cold north Atlantic where low temperature and associated biological activity were assumed to aid in the preservation of shipwreck materials, particularly organics (Livingstone 1975), such was not the case. The wood-boring mollusc, *Xyloredo ingolfia*, a deep water relative of the warm water *Teredo,* was reported in large numbers on the ship.

The biology of the *Teredo* shipworm is well documented (Nair and Saraswathy 1971). Weiss (1948) observed the actual preservation of wood from *Teredo* attack by barnacles that fouled wooden surface areas. *Teredo* represents only one genera of shipworms. Two others are ***Bankia*** and ***Martesia*** **(Hunt and Garrat 1967).** The shipworms are found in most coastal waters and frequently attack exposed surfaces at or near the mud line.

Crustaceans also affect woods. *Limnoria, Sphaeroma*, and *Chelura* are found in American waters. *Limnoria* and *Sphaeroma* belong to the order Isopoda while *Chelura* is an *Amplipodea* (Hunt and Garrat 1967). *Limnoria* is the most destructive in the Gulf and invade the same timbers as shipworms.

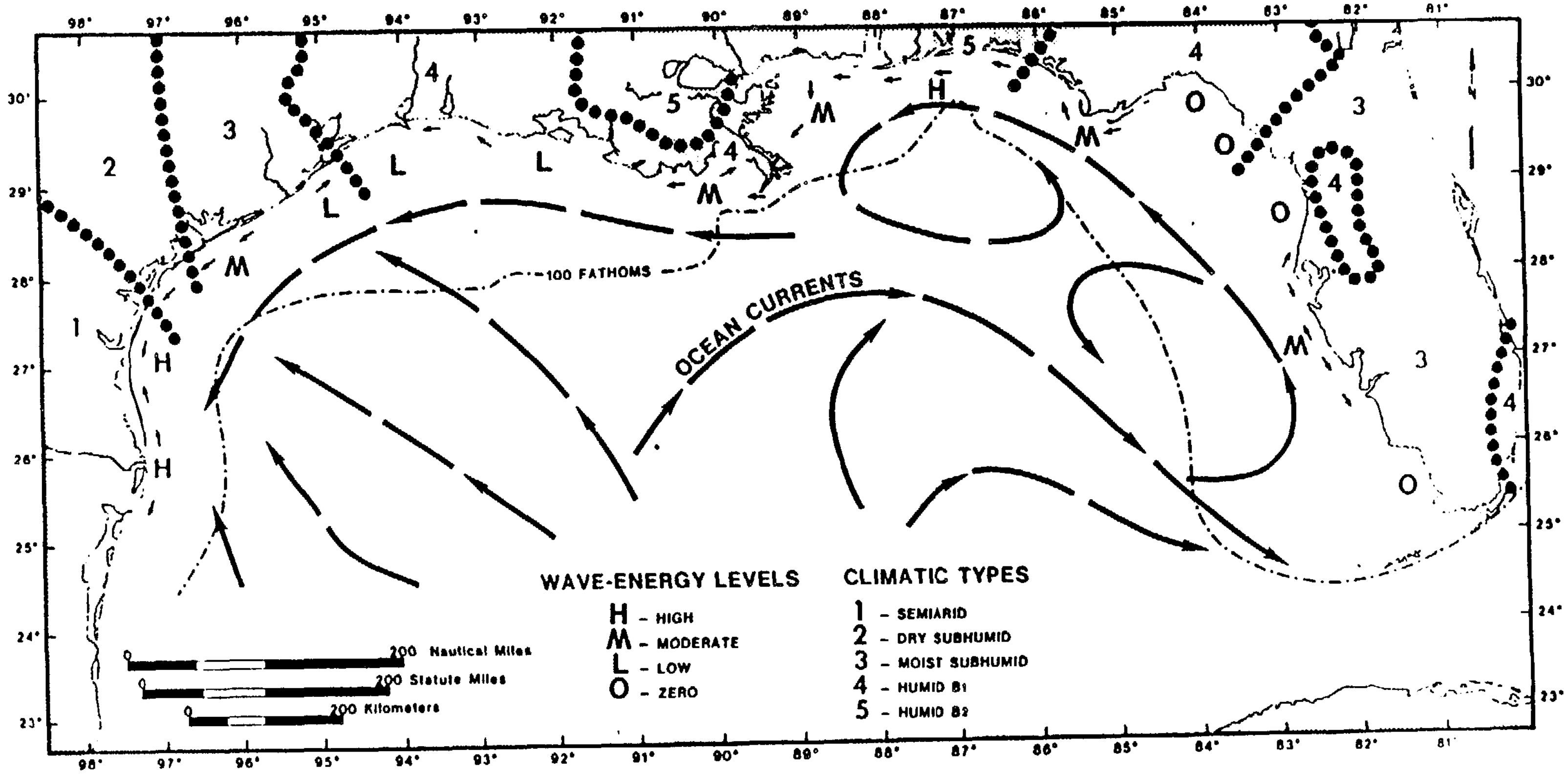


FIGURE II-19. Some major process parameters of the northern Gulf of Mexico (after Kwon 1969).

No woods are known to be naturally immune to destruction by marine borers. Heartwoods of certain kinds have been found to offer resistance to attack. The most resistant woods are foreign woods such as jarrah, totora, turpentine wood, azobe, manbarklak, angelique, and greenheart (Hunt and Garrat 1967). Native woods such as pine, fir and oak are soon destroyed unless some form of artificial protection is provided such as impregnation, coatings, or sheathing.

Coupled with other benthic organisms and aerobic bacteria, the organic remains of shipwrecks are metabolized in sediments. Low dissolved oxygen promotes the growth of sulfide bacteria typically associated with muds (Evans 1963; Pearson 1972; Richards 1957). The impact of sulfide reducing bacteria is principally on metals rather than organic materials (Hamilton 1976). These organisms are the suspected cause of the extensive corrosion seen on TITANIC (Ryan 1987).

8.1.2.2 Electrochemical and Biological Corrosion

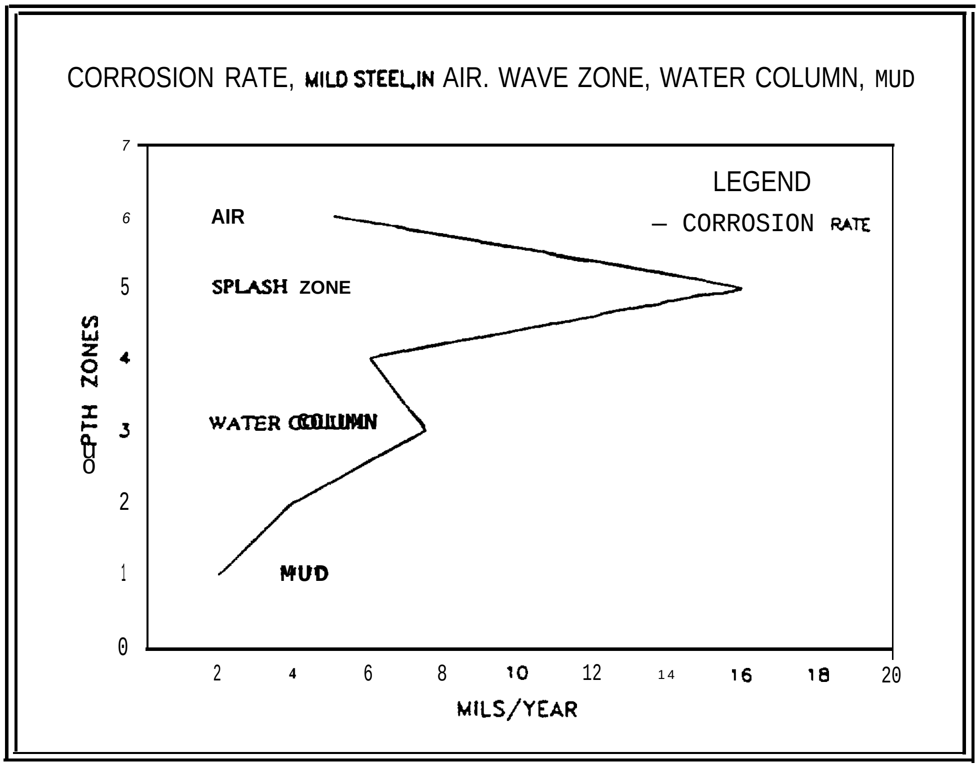
Electrochemical activity is the longest lasting and most detrimental portion of the decomposition cycle for a shipwreck site. Sediment overburden can reduce the corrosion rate but will not stop until the metal reaches electrochemical equilibrium (Brown 1987). In the electrochemical process iron goes into solution as iron hydroxide which is oxidized into hydrated ferric oxide (rust). The corrosion rate of the metals drops off significantly in clean mud (Warren 1980)(Figure 11-20a).

Cornet (1970) states that iron corrodes ten times faster in sea water than in air and five times less in soil. In comparing steel to wrought iron used in many 19th century vessels, there is no direct technical evidence that wrought iron rusts more slowly than steel in the sea (Warren 1980). Sulfate bacteria are responsible for as much as 60 percent of corrosion in salt water. These are typically strains of *Sporovibrio desulphuricans* (Pearson 1972) and *Desulphovibirio desulphuricans* (Farrer 1953). Hamilton (1 976) attributes this to continued bacterial oxidation after electrochemical equilibrium has been reached (Figure 11-20 b).

Other metals susceptible to corrosion and encountered in shipwrecks are tin and brass. Brass is susceptible because it contains zinc. When zinc dissolves it leaves a spongy mass of copper (Warren 1980). Tin oxidizes to tin oxide (Warren 1980). The noble metals (of which copper is one) are resistant to corrosion while silver is susceptible to sulfide formation (Hamilton 1976).

8.1.2.3 Dissolved Oxygen (DO)

A correlation between organic content of the sediments and dissolved oxygen content of water was suggested by Richards (1957). In the western Gulf, an oxygen minimum layer can seasonally impinge on the bottom because of the relatively high organic content in the surface sediments. Since corrosion decreases as DO decreases, there may be a higher chance of finding metallic artifacts in sediments with a high organic content (Chandler 1973). Large areas of hypoxia (i.e., concentrations of dissolved oxygen lower than 2 mg/l) regularly develop off Louisiana west of the Delta (Pokryfki and Randall 1987). Dennis (1984), Rabalais (1985) and Renaud (1985) also produced extensive bibliographies on hypoxia. Hypoxia occurs in Texas coastal waters, but less frequently. Pokryfki and Randall (1987) measured the spatial extent of hypoxia in coastal waters from Galveston, Texas to Cameron, La. in July 1974. Their results for concentrations of dissolved oxygen on the bottom are shown in Figure F-8. They note that the hypoxic mass of bottom water lay entirely inshore of the 20 m isobath and was not an extension of the oxygen minimum layer that impinges on the outer shelf from the deep Gulf.



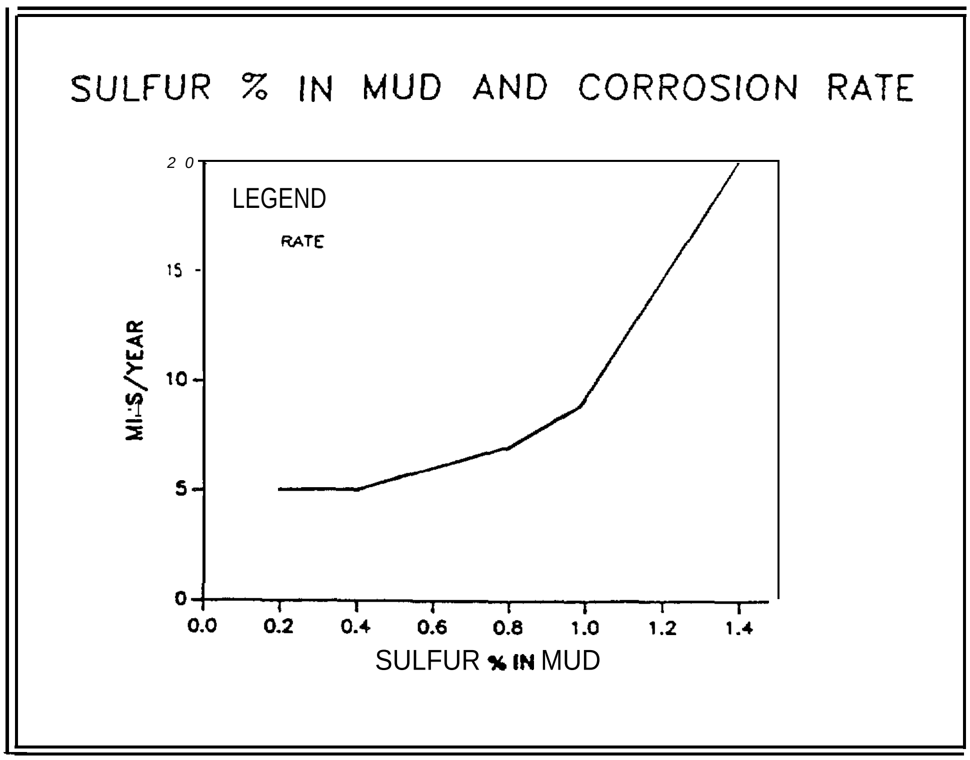


FIGURE II-20. (a) Corrosion rates In sea water, air and mud
(b) Corrosion rates versus sulphur content In mud.

8.1.2.4 Currents and Corrosion Rates

The impact of currents on shipwrecks depends on other factors. In the initial wrecking phase, the currents, in association with shallow water wave action, break apart, erode and scatter wreckage (Muckelroy 1978). At the same time scour around shipwreck debris can bury parts of the wreckage depending on sediment transport. Low sediment deposition in deeper water tends to preclude burial other than lower hull elements.

Current velocities influence corrosion rates of metals, notably iron. A water flow of -0,5 m/s (1 knot) encourages rusting of steel. At 1 m/s the rate is three times higher (Warren 1980). The rate rises to eight times that of static water at 6 m/s. The rate also varies with temperature, doubling every 10° C rise in temperature up to about 80° C and decreasing as oxygen decreases (Chandler 1974). Miller (1985) considers the USS MONITOR highly corrosive due to the relatively high temperature, oxygen content, and current velocity at the site.

8.1.3 *Environmental Factors in Shipwreck Preservation*

We can define a range of environments in which shipwrecks occur with the range being: (1) static and hypoxic, and (2) dynamic and aerobic. The static-hypoxic environment is considered conducive to preservation (Chandler 1974). This type of site would be characterized by a mud/silt environment in a low DO area e.g. Louisiana or Texas. However, preservation is still affected by the interaction of other chemical factors. Pollutants can accelerate metal corrosion rates. Composites such as wood-iron structural joinery can continue to corrode or rot due to the interaction of certain woods and iron. Oak will accelerate iron corrosion due to the tannic acid in the wood (Warren 1980). Hamilton (1976) cites bacterial corrosion in anoxic conditions even inside encrustations.

The other type of environment, dynamic-aerobic, would have sands or detrial sediments in a zone of strong bottom currents, e.g. the upper Texas or west Florida shelf. Here, temperature, current velocity and oxygen content would promote abrasive erosion of exposed surfaces, biological attack and accelerated corrosion of metallic materials.

Figure II-21 summarizes environmental factors in shipwreck preservation. The postulated relationships are shown in a schematic using a rank scale of low to high for the variables. The coarse sediment deposits with high current velocity, biological activity, DO, and corrosion rates would be characteristic of a dynamic-aerobic environment with poor overall preservation. The converse, would define the static-anaerobic environment with a higher probability of overall preservation of shipwreck materials.

Muckelroy (1 978), following Hiscock (1974) and King (1972), evaluated 11 environmental attributes potentially affecting the preservation of shipwrecks. Of these, three relate to sediments: (a) topography; (b) the coarsest material in deposits; and (c) the finest material in deposits. Water movement (e.g. energy zones) plays a minor role in preservation.

We examined five out of eleven of Muckelroy's original factors affecting shipwreck preservation because some of Muckelroy's variables were not truly independent. For example, current velocity and dissolved oxygen are directly related in almost all situations (Figure II-21). We propose, as did Muckelroy, that the main determining factor in the survival of archaeological remains is sediment type and distribution. We examined a series of shipwrecks representing five classes of sites as defined by Muckelroy (1 978) to test this hypothesis. These classes are:

Class 1 Extensive structural remains, many organic remains and other objects in a coherent distribution
Classes 2 & 3 Elements and fragments of the hull some to many organic and other objects in a scattered distribution
Classes 4 & 5 No structure few to no remains in a scattered, disordered distribution

We approached the relationships involved in shipwreck preservation by examining sediment type and burial depth on known wrecks. The data are drawn from sources not available to CEI and present a clearer understanding for preservation relative to specific sediment facies and shelf characteristics. The study draws heavily on earlier, comprehensive studies of shelf sediments such as Curray (1960; 1965); Nelson and Bray (1970); Van Andel (1960); Scruton (1960); Bouma (1972), Rezak, et. al. (1985); and Berg (1986) and integrating with unpublished shipwreck survey data (Smith 1978).

To do this in a systematic matter, a conceptual model of the continental shelf was used where sediment facies were organized across a matrix of the Inner, Middle, and Outer Neritic Zone within the western, central, and eastern provinces of the northern Gulf. Longshore facies and delta areas were treated separately for their preservation potential.

The analysis includes an archaeological inventory of known shipwrecks from various shelf regions. The study identifies the differential preservation of shipwreck materials (hull, superstructure, cargo) the spatial aspects of the shipwreck sites; and how factors, such as bottom sediment type, and thickness of unconsolidated sediments, interact with other factors, such as associated biological activity or waves and energy zones. Correlations with biological activity, sediment facies and burial depth are observed. Other associations occur with surface waves and coastal energy zones.

Eighteen wreck sites in the Gulf, Atlantic and Caribbean are examined in Table II-14. The distribution of the remains of structural and organic elements and other objects are used to measure the proposed relationship between sediments and preservation. We deviated from Muckelroy's methodology by necessity as the environments of British wrecks differ somewhat from those in American waters.

Figure II-22 illustrates the location, type and relative amount of structural remains typically found at each site. The schematic view lists only major decks and does not show any standing rigging. It does allow a conceptualization of the preserved remains of an early historic shipwreck such as those discussed for Molasses Reef (Keith and Simmons 1985; Smith and Keith 1986; Oertling 1986); Highborn Kay (Smith 1985); *SAN ESTEBAN*; *ESPRITU SANTU* (Arnold **1978;** Arnold and Weddle 1978); and, to lesser degree, later Spanish wrecks of 17th and 18th centuries such as SAN JOSE (Smith 1978).

Table II-14 does not yield a definitive picture of the relationship of preservation to environment but some conclusions can be drawn:

a. Structural remains are poorly preserved in nine cases where the vessels were sunk in dynamic, coarse sediment environments. The ESPIRIT SANTO had no structural remains;
b. Organic remains were not preserved or poorly so in 11 cases. All of these cases involve dynamic, coarse sediment environments. The MARY is an exception;
c. Preservation of other objects vary widely across the sample with little observed correlation with the specific environmental variables selected in this example;
d. Discontinuous wreck sites occur only in dynamic, coarse sediment environments; and
e. 19th century wrecks, are more preserved than earlier 16-1 8th century wrecks.

Relative Preservation Potential Scale

LOW		HIGH
High	⟷	Low (current velocity)
High	⟷	Low (biological activity)
High	⟷	Low (dissolved oxygen)
High	⟷	Low (corrosion rate)
Sands (coarse)	⟷	Muds (sediment type) (fine)

FIGURE II-21. **Hypothesized relationships of sediments,** energy, chemical, biological factors and preservation of shipwreck materials.

Table II-14.

SPECIFIC SHIPWRECK CASES: THEIR PRESERVATION AND **ENVIRONMENTAL FACTORS.**

Site Name	Period (century)	Structural Remains	Organic Remains	Other jects	Distri-bution	Current elocity	Biological Activity	Dissolved xygen	Corrosion ate	Sediment ype
Molasses Reef Wreck(l)	16th	≤ a	0	FEW	CONT.	HIGH	HIGH	HIGH	HIGH	CORAL SAND
Highborn Key Wreck(2)	16th	≤ a	FEW	FEW	CONT.	HIGH	HIGH	HIGH	HIGH	CORAL SAND
San Esteban (3)	16th	keel fragment	0	MANY	DISCONT.	HIGH	HIGH	HIGH	HIGH	SAND SHELL
Espirutu Santo (4)	16th	0	0	MANY"	DISCONT.	HIGH	HIGH	HIGH	HIGH	SAND SHELL
New Ground Reef Wreck(5)	16th	≤ a	FEW	MANY	CONT.	MOD	HIGH	HIGH	HIGH	CORAL
Nuestra Senora de Atocha(6)	17th	≤ a	FEW	MANY	DISCONT.	HIGH	HIGH	HIGH	HIGH	SAND
El Capitan(7)	18th	≤ a	FEW	MANY	CCNT.	MOD	HIGH	HIGH	HIGH	CORAL
El Lerri(7)	18th	≥ a	FEW	UNK.	CONT.	MOD	HIGH	HIGH	HIGH	SAND CORAL
San Jose(7)	18th	a, b	FEW**	MANY	CONT.	HIGH	HIGH	HIGH	HIGH	MUD SAND GRASS
Augustias(7)										
El Nuevo	18th	≤ a	0	FEW	CONT.	HIGH	HIGH	HIGH	HIGH	ROCK
Constante(8)	18th	≤ a	MANY	MANY	CONT.	LOW	LOW	Low	LOW	SILT CLAY
Will O' The Wisp(9)	19th	a-b	UNK.	UNK.	CONT.	HIGH	HIGH	HIGH	HIGH	SAND
USS Hatteras(10)	19th	a-d	UNK.	UNK.	CONT.	LOW	MOD	MOD	MOD	SILT MUD
Hillsboro Beach Wreck(1 1)	19th	≥ a	FEW	MANY	CONT.	HIGH	HIGH	HIGH	HIGH	SAND
Mary(12)	19th	≥ a	MANY***	UNK.	CONT.	HIGH	HIGH	HIGH	HIGH	SAND
USS Monitor	19th	90-100%	UNK.	MANY	CONT.	HIGH	MOD-HIGH	HIGH	HIGH	SILT SAND
Acadia(14)	19th	≥ a	UNK.	MANY	CCNT.	HIGH	HIGH	HIGH	HIGH	SAND

Table II-14
(continued).

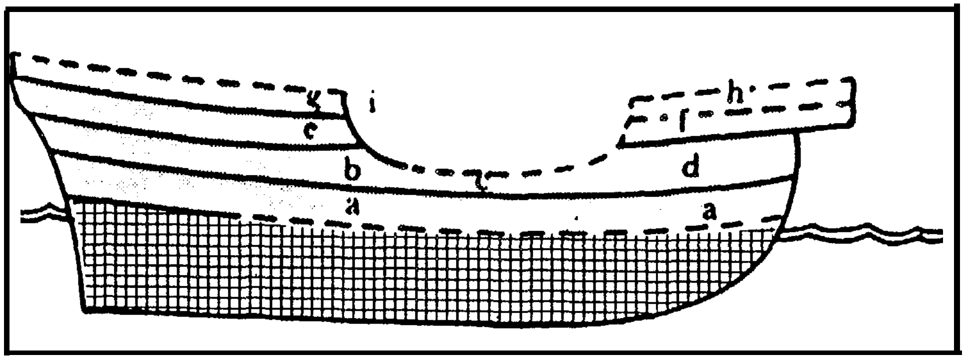
(1) Keith and Simmons, 1985; (2) Smith, et at, 1985; (3) Arnold 1978; Arnold and Weddle 1979; (4) ibid (5) Parrent 1985; (6) Mathewson 1977; 1986 (7) Smith1 978; (8) Pearson 1981; (9) Larry R. Martin, personal communication, 1988; (1 O) Melancon 1976; (11) Woolsey, ORN, Ser 1, Vol 22; (12) Corpus Christi Caller-Times, 1987; (13) Miller 1985; (14) Hole 1974

Notes:

• No provenance on finds (see Arnold and Weddle 1978: 25-27)

** Partial human skull, first ever found on New World' s shipwreck

*** Burlap detected in 1987 during inspection by remote-operated vehicle (ROV)



Portion of vessel most likely to be preserved

Portion of vessel most likely not to be preserved

(a) The overlop, or nether overlop, or upper lop.
(b) The somercastle, or nether deck, or barbican.
(c) The waist.
(d) The nether deck in the forecastle.
(b) (c) and (d) together are occasionally called the upper overlop.
(b) and (c) together are frequently called the nether deck.
(i) The breast of the ship.
second deck.
(f) The middle deck in the forecastle, or the upper forecastle.
(g) The highmost or highest deck, or the upper deck, or the deck; or (probably when shortened to a poop) the small deck.
(h) The upper deck in the forecastle (not in small ships).

FIGURE II-22. **Structural preservation, 16-18th century vessel.**

Based on this review, preservation is enhanced in fine-grained sediment and low energy environments (ex. **EL NUEVO CONSTANTE; USS HATTERAS)** and reduced in coarse grained sediment and dynamic environments (ex. ESPIRITU SANTO; USS. MONITOR). Further, preservation of structural fabric in early shipwrecks appears to be reduced where salvage efforts were conducted. This seems most prevalent in Spanish examples (SAN ESTABAN, ESPIRITU SANTO, EL CAPITAN, EL LERRI, SAN JOSE) where salvaged vessels in the lower energy, finer-g rained sediment environments are better preserved. In coarser-grained sediments, where energy levels are high, such as nearshore and barrier-spit environments, rapid burial clearly reduces the deterioration due to biological activity.

In deeper water, but with coarse-grained bottom sediments, preservation can be enhanced by low oxygen levels in pore water due to turbidity. Such conditions exist on the northwestern Gulf of Mexico shelf in the summer months (Rezak, et. al. 1985). Indeed the nephloid layer may act as an agent in the reduction of organisms or chemical reactions at certain periods in large areas of the northwestern Gulf.

This survey considered a small sample of shipwrecks in the Gulf or nearby waters which have had a degree of archaeological expertise applied to the study of their remains. Shipwreck archaeology with scientific site surveys and excavation of Gulf shipwrecks is recent and incomplete. **We** summarize our survey's results in the following chart of sediment environments postulating an expected probability, low to high, for preservation of historic shipwrecks. Using this model, preservation of historic shipwrecks is expected to be highest on the northwest Gulf of Mexico continental shelf west of the Mississippi River delta and low on most of the eastern Gulf's shelf areas (Figures II-23 and II-24).

SEDIMENTS AND PRESERVATION POTENTIAL

• SANDS	LOW
• SANDY/SILT	LOW– MOOERATE
• SILTS	MODERATE
• SILTY/CLAY	MODERATE-HIGH
• CLAY	HIGH

FIGURE II-23. Expected preservation potential ● nd ● edhnent distribution, northern Guif of Mexico.

GULF SEDIMENT AREAS AND EXPECTED PRESERVATION POTENTIAL

RIO GRANDE AREA	NIGH
WESTERN AREA	HIGH–MODERATE
CENTRAL AREA	MODERATE–LOW
CENTRAL LOUISAMA AREA	HIGH–MODERATE
MISS/ALABAMA AREA	LOW–MODERATE
WEST FLORIDA AREA	LOW–MODERATE
BIG BEND AREA	LOW
MIDDLE GROUND	LOW
SOUTHWEST FLORIDA AREA	LOW
DRY TORTUGAS AREA	Low

FIGURE ii-24. Gulf sediment areas and expected preservation potential.

9.0 INTERPRETATION OF SHIPWRECK DISTRIBUTION PATTERNS

9.1 Introduction

Patterns exist in man's social milieu. Behavioral variations combine with natural factors to produce specific patterns. The explanation of shipwreck distribution patterns is the same as for the spatial distribution of sites of other artifacts. Shipwrecks of the northern Gulf of Mexico are the product of historical and natural factors. Ships played a key role in long distance transport of goods, people and ideas. The patterns of the shipwrecks of the northern Gulf of Mexico mark the important routes of the economic and political past while their density give indications of the perils along those routes.

9.1.1 Methods *of Shipwreck* **Pattern Analyses - *Other* Studies**

This study has benefited from earlier studies of shipwreck patterning conducted by other authors (CEI 1977; Bourque 1979; SAI 1981; and Pierson 1987). The CEI (1977) investigators compiled an encyclopedia listing of shipwrecks and drew conclusions based on these data. Their conclusions should be cast as hypotheses on the temporal and spatial distribution of shipwrecks. They estimated the number of shipwrecks in the Gulf of Mexico to be between 2,500 to 3,000. Further they projected that 80 to 90 percent of these wrecks are located within 10 km of the present coastline. They expected concentrations of shipwreck sites to be associated with areas of marine traffic such as at the approaches to seaports, mouths of navigable rivers, straits, shoals and reefs. They recognized that certain areas in deeper water, where shipping lanes have crossed for centuries had numerous shipwrecks, but felt expected higher incidence for wrecks in these areas did not warrant special treatment. Finally, they predicted the shipwreck population to fall into a bell-shaped distribution with a peak in the period of 1800 to 1910.

Bourque (1979) in the cultural resources baseline study for the Atlantic OCS measured shipwreck densities with specific depth ranges over time. He did not directly use the complete set of shipwreck locational data in his analysis. His method of evaluation concentrated on shipping data. Like CEI, he projected a peak for vessel losses in the period of 1800-1880. The locations of shipwrecks were assigned positions within an area of six or fewer lease blocks or simply classified as "6X" (general location known, but not within 6 lease blocks). The result of these analyses produced a model that predicted shipwreck density within shipping zones.

SAI (1981) followed the generalistic approach of CEI. An exhaustive list of shipwrecks was compiled for the OCS from Cape Hatteras to Key West. The effort derived a general correlation of shipwreck density with specific areas and factors. The investigator identifies "clusters" of shipwrecks in time and space. The approach is fundamentally inductive and non-numerical. The author does examine sample bias in a broad sense and speculates on its affect on the recognition of true patterns. Factors responsible for these concentrations of shipwrecks are identified as increased commerce, warfare and natural hazards such as the Florida reef tract.

Pearson (1987) generated a computerized shipwreck data file. From this database the authors developed a model using "prediction factors" such as port or anchorage, hazard, shipping route and number of reported sites. These factors weighted the data in specific locales and were used to isolate sensitive areas for the occurrence of shipwrecks. These factors are deterministic and random site occurrences are projected for areas outside zones near seaports, islands, hazards, and traffic lanes. No measures of dispersion were given for the characterization of randomness so the nature of the Pearson study is not statistical.

Other studies of shipwrecks exist for areas along the northern Gulf of Mexico. These reports are generally cultural resource studies of specific ports or entrance channels such as Galveston (NOAA 1988, Hudson 1979), Pensacola (Tesar 1973), Mobile (Mistovich and Knight 1983), Gulfport (Mistovich 1987), Pascagoula (Mistovich, Knight and Solis 1983), Freeport (Bond 1981), and Brownsville (Espey, Huston & Assoc. 1981). None of these studies produce more than an inventory of shipwrecks within their given project area. No higher level syntheses are attempted although the compilation of data is impressive. Typically the reports locate known or suspected shipwreck sites and correlate these locations with historical and instrumental survey data.

9.1.2 *Methods of Shipwreck Pattern Analyses - This Study*

We have compiled shipwreck data from a number of sources and created a computerized data base. This follows Pearson (1987) more than the CEI, SAI, and Bourque efforts. The frequency of shipwrecks was examined over 50 year periods or every 20 years after the 20th century. The distribution of shipwrecks was examined using simple numerical techniques after the data were placed in quadrants of 0.5 and 1.0 degrees, or roughly 2304 and 9216 sq km, respectively. The data were also sorted according to MMS lease block areas (23 sq km).

We followed over a decade of investigators in the formal analysis of spatial data (Clarke 1 977, Hodder and Orton 1976, Orton 1982, Hietala 1984, Johnson 1984, and Neft 1966). The data were examined using factor analysis (Cooley and Lohnes 1962, Rowlett and Pollnac 1970) and distribution analysis (Hodder 1977).

Figures II-25 through II-36 show the distribution and frequency of shipwrecks from 1 500 to the present. These plots show shipwrecks within OCS lease blocks, with the exception of those for 1500-1599. Plots with shipwrecks exclusively within state lands are shown in Appendix H. The geographic (x-y) coordinates assigned to the vessels allow us to apply spatial techniques with the scatter plots that this sequence of maps represent. The trend is in the increased frequency for shipwrecks over time. A bias for the underreporting of losses exists in the early periods, but this *recognition* must also consider that fewer vessels sailed the Gulf waters during those times. The method used to assign coordinates to these data are discussed below before continuing with other data analyses.

9.1.3 Chronological Trends: 16th-20th Centuries - Summary

The frequency of shipwrecks from 1500 to 1986 are tabulated in Table II-15. Chronological trends in the shipwreck patterns correlate with general historic factors such as Flota cycles, colonization, commerce, and shipping routes. The data are divided into 50 year periods from 1500-1899 and 20 year increments thereafter (Table 11-16).

The chronological trend reflects the increase in shipwrecks with time. The increase coincides with settlement of the northern Gulf coast after 1700. Before this time losses were sporadic and concentrated at the Straits of Florida.

Another factor in this trend is the reporting of losses. In the early periods vessels with no survivors were simply “lost” with little in the way of accurate reports of their fate. The numbers for these periods are conservative by an unknown amount.

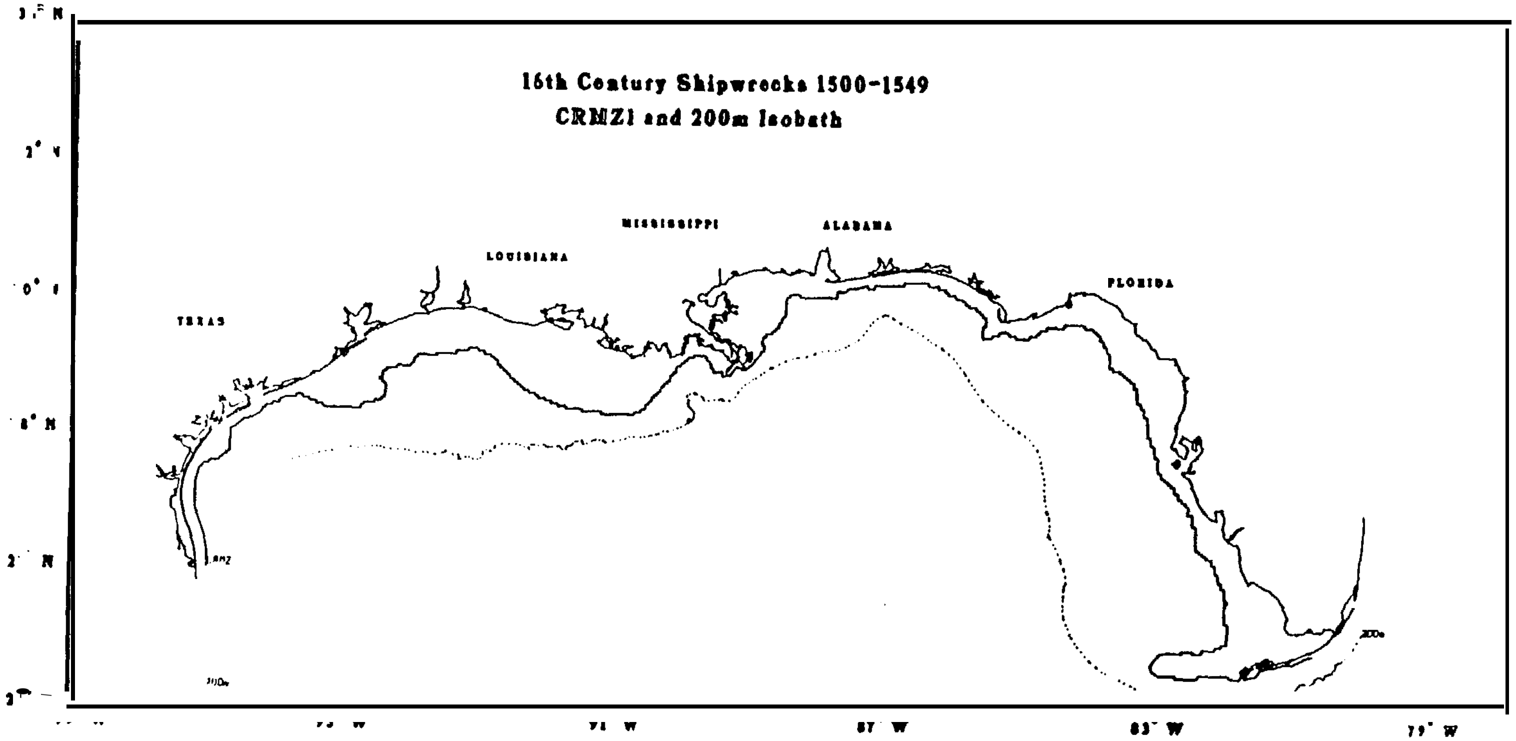


FIGURE II-25. Shipwreck positions, 1500-1549.

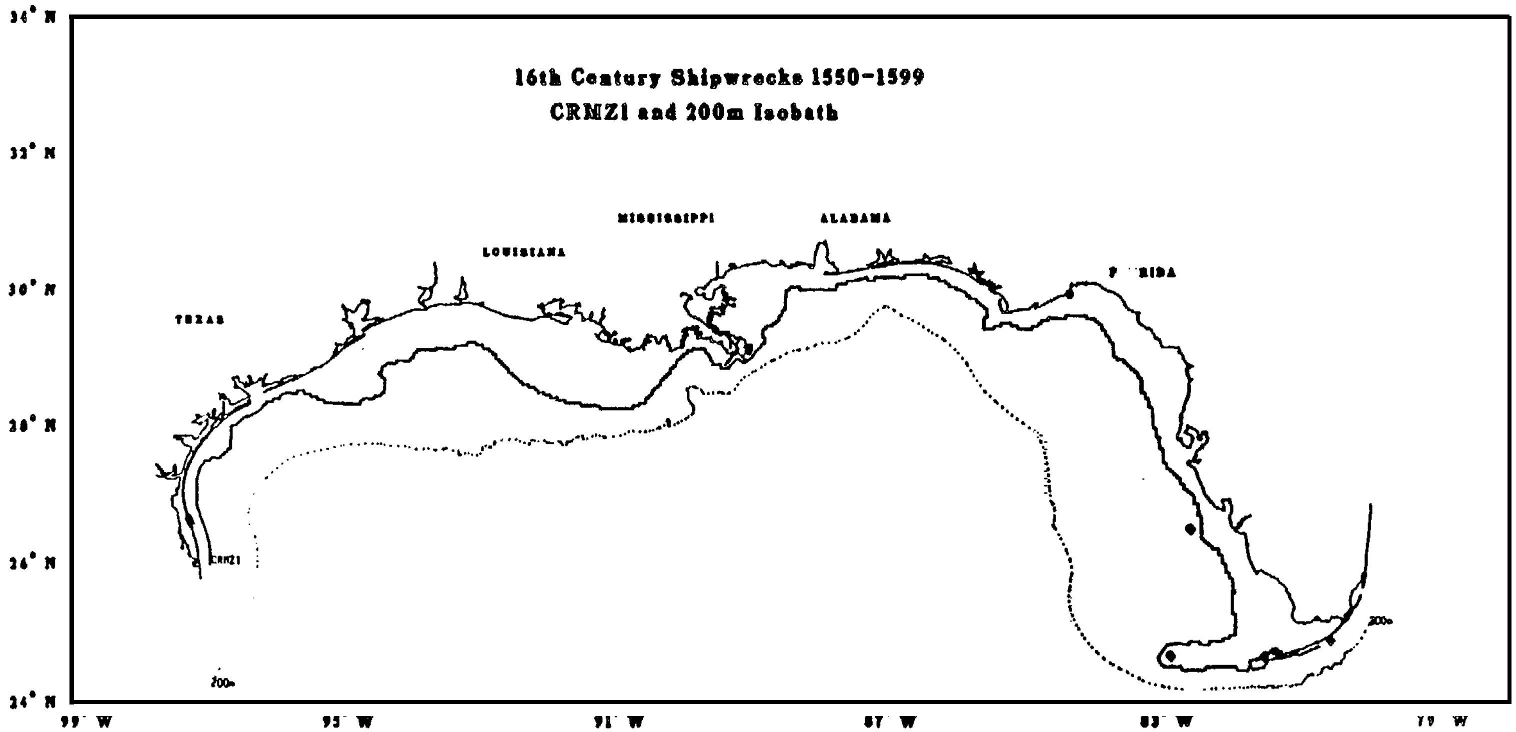


FIGURE II-26. Shipwreck positions, 1550-1599.

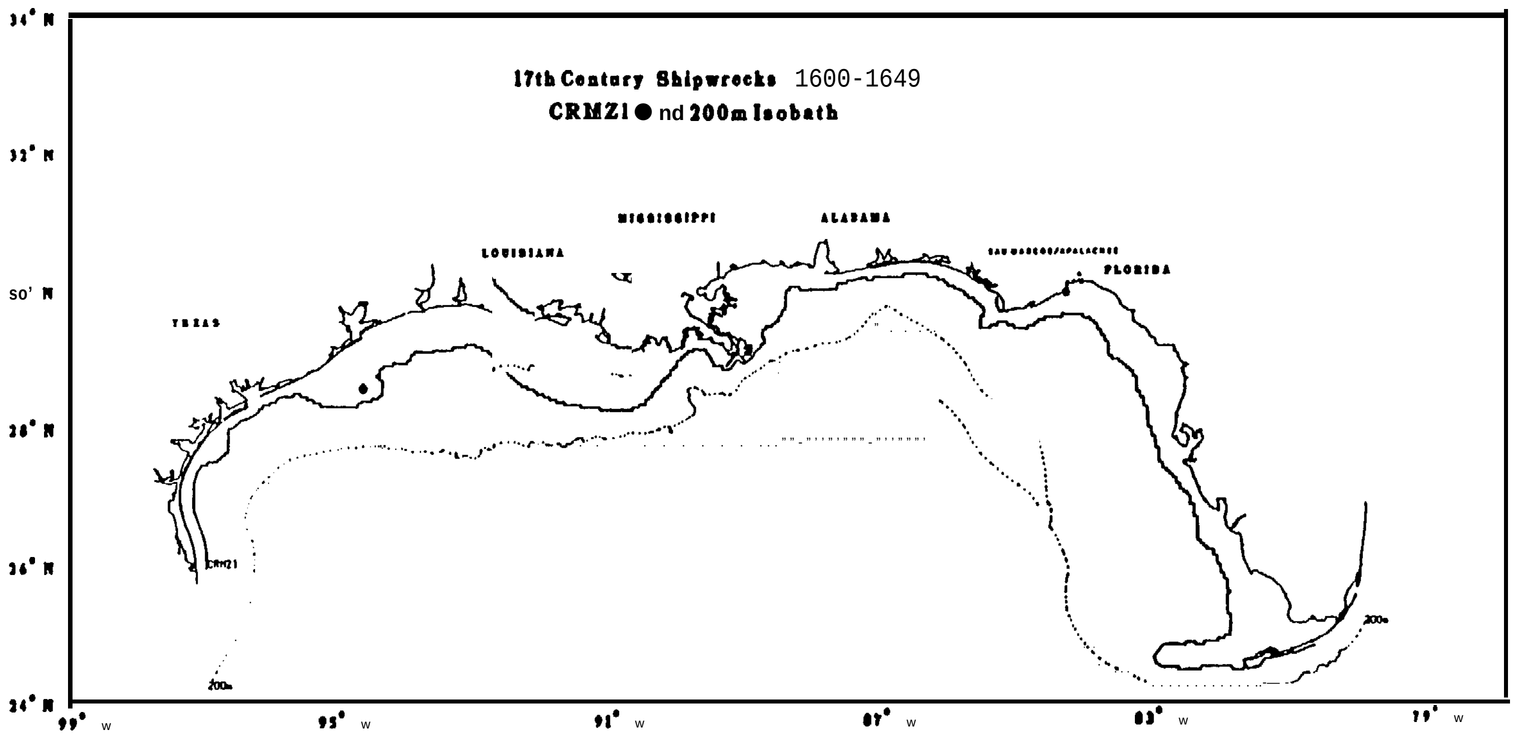


FIGURE II-27. **Shipwreck positions,** 1600-1649.

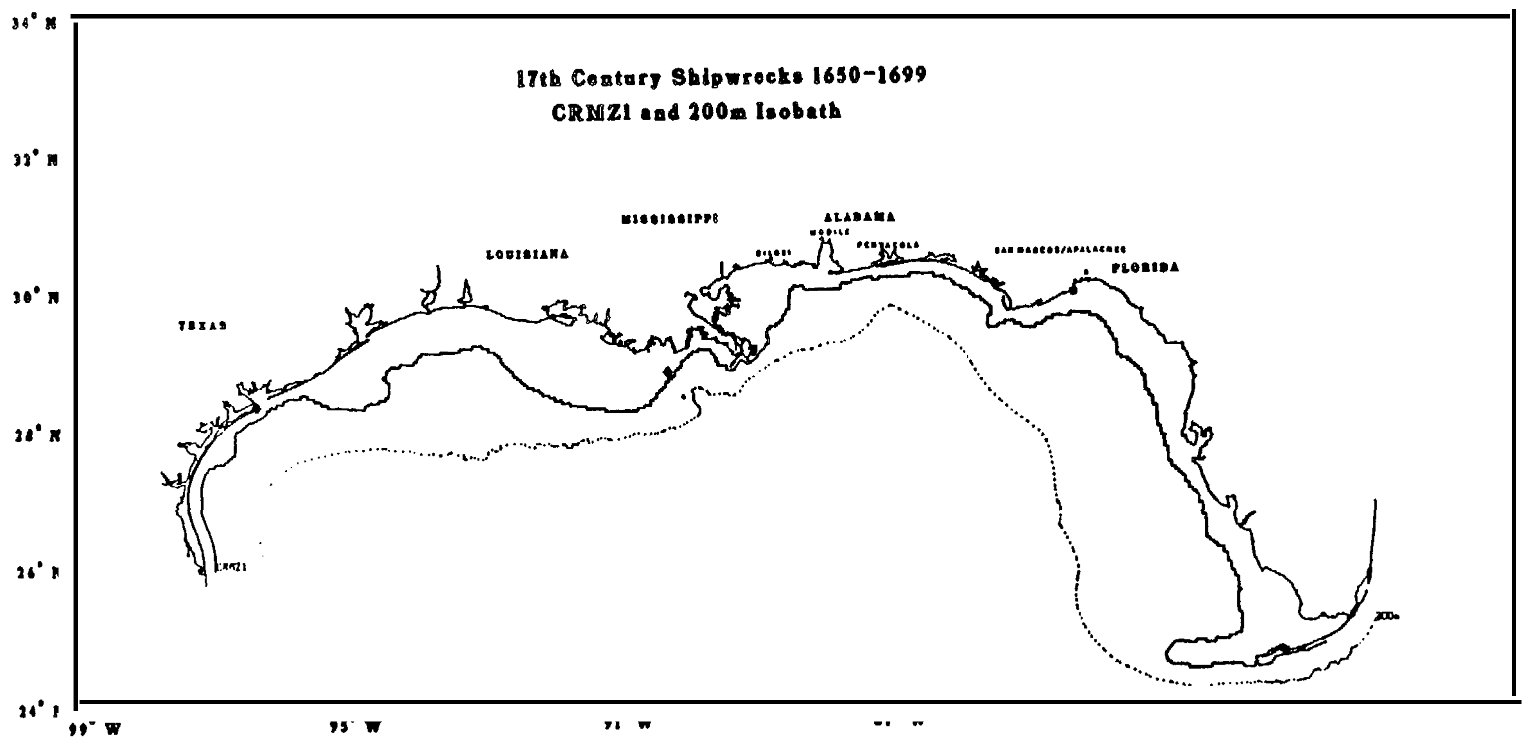


FIGURE II-28. Shipwreck positions, 1650-1699.

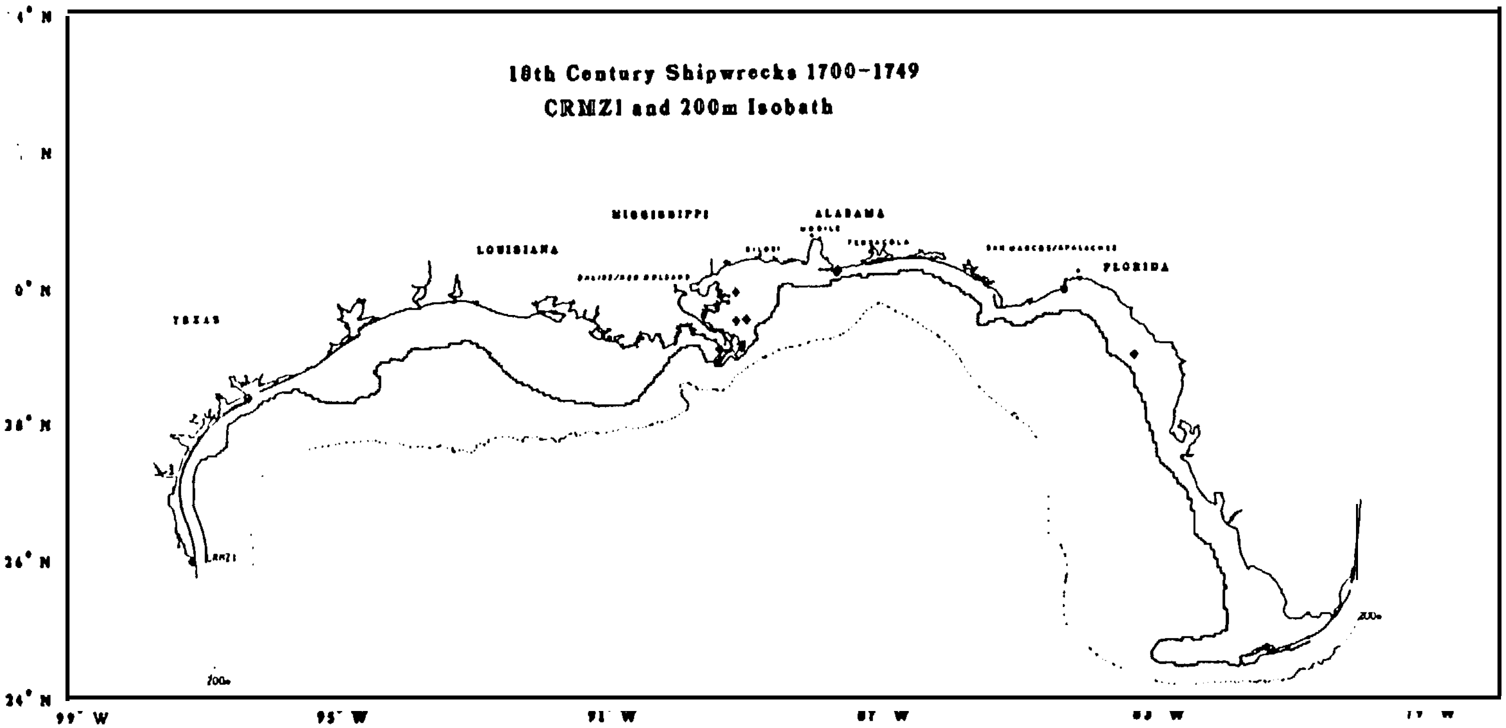


FIGURE II-29. Shipwreck positions, 1700-1749.

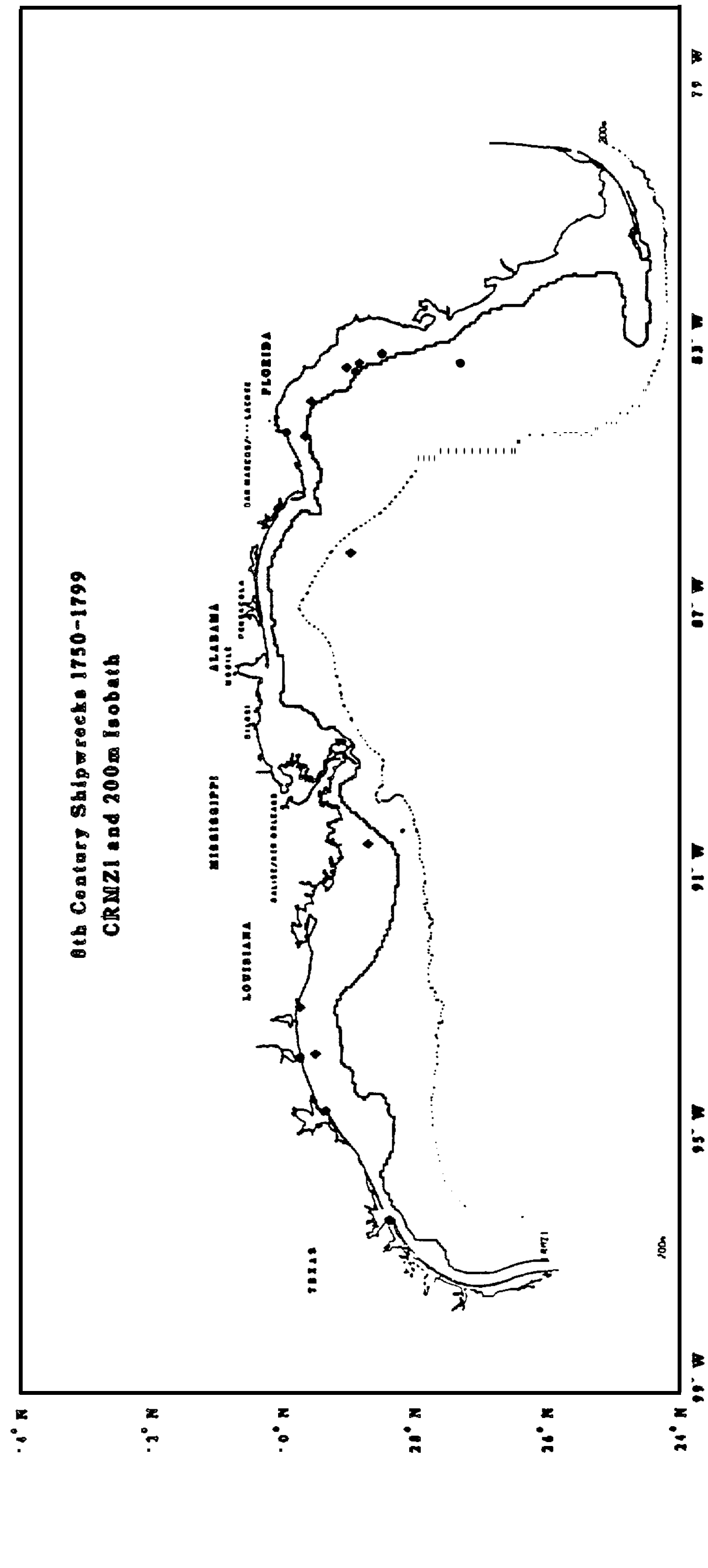


FIGURE II-30. Shipwreck positions, 1750-1799.

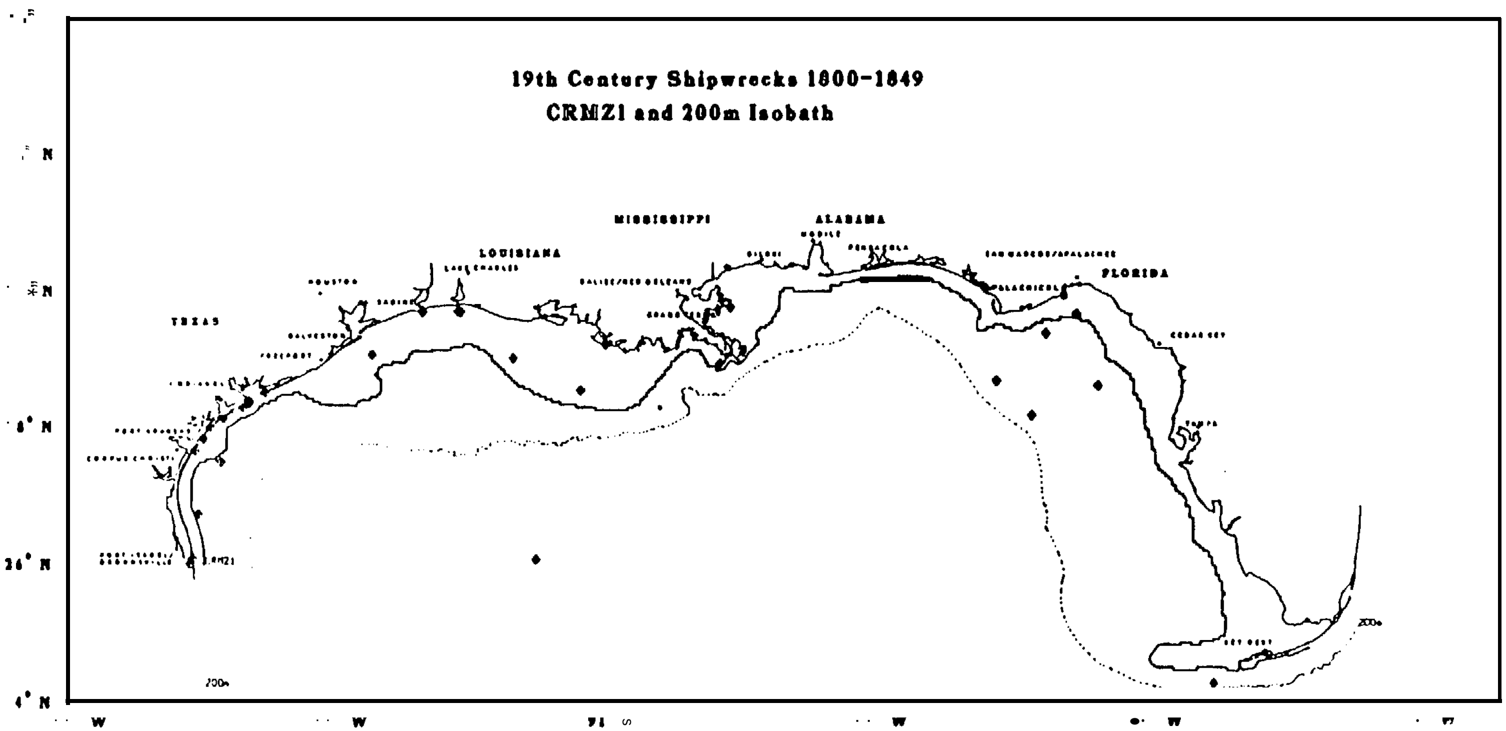


FIGURE II-31. Shipwreck positions, 1800-1849.

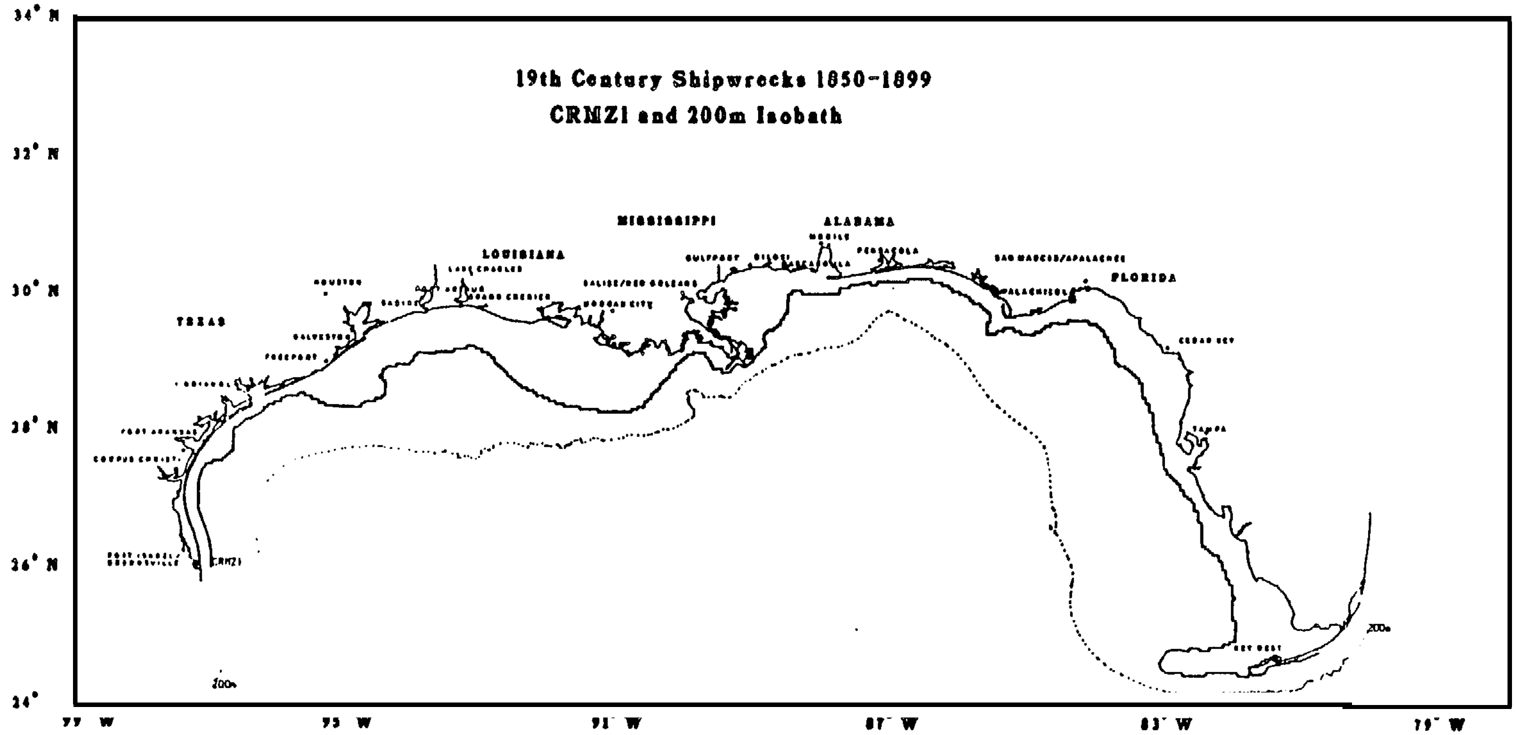


FIGURE II-32. Shipwreck positions, 1850-1899.

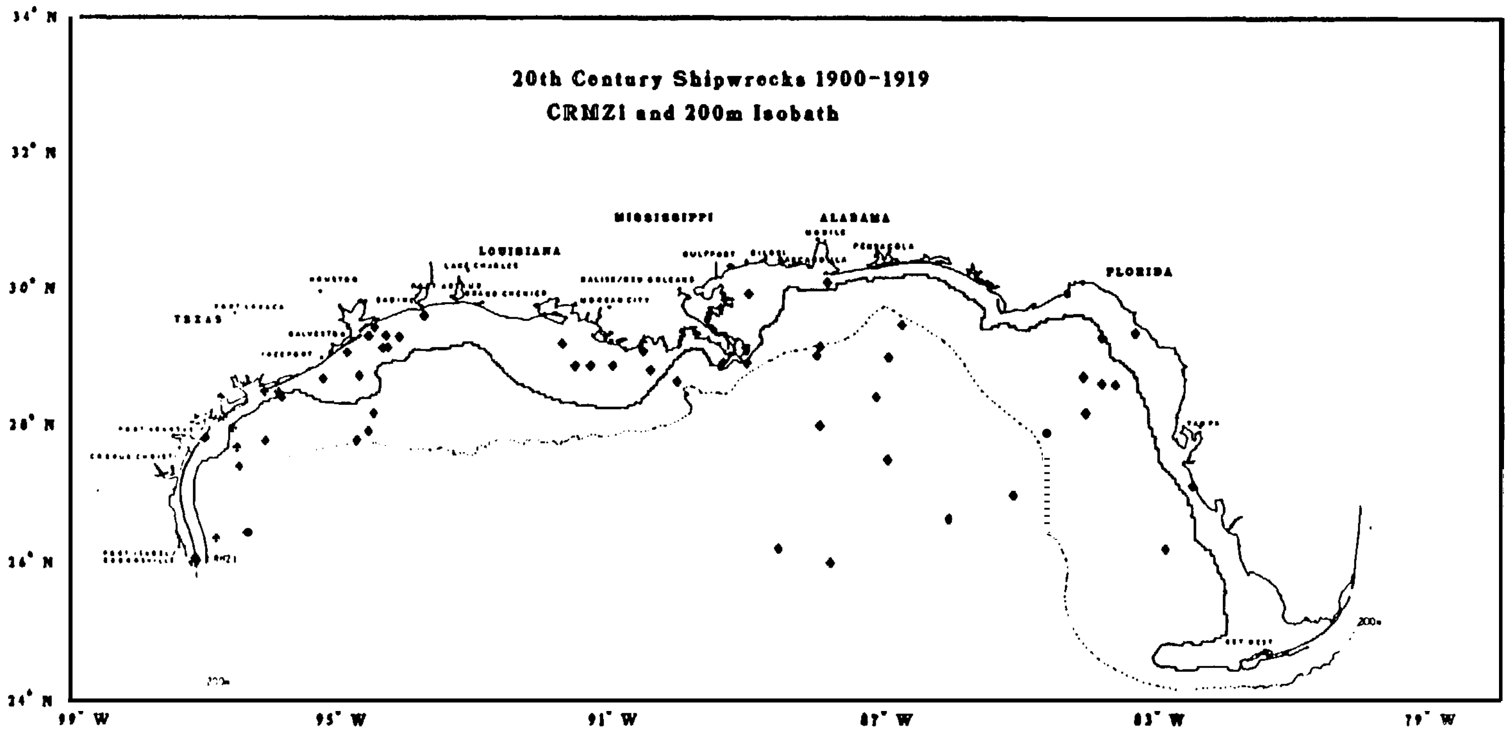


FIGURE II-33. Shipwreck positions, 1900-1919.

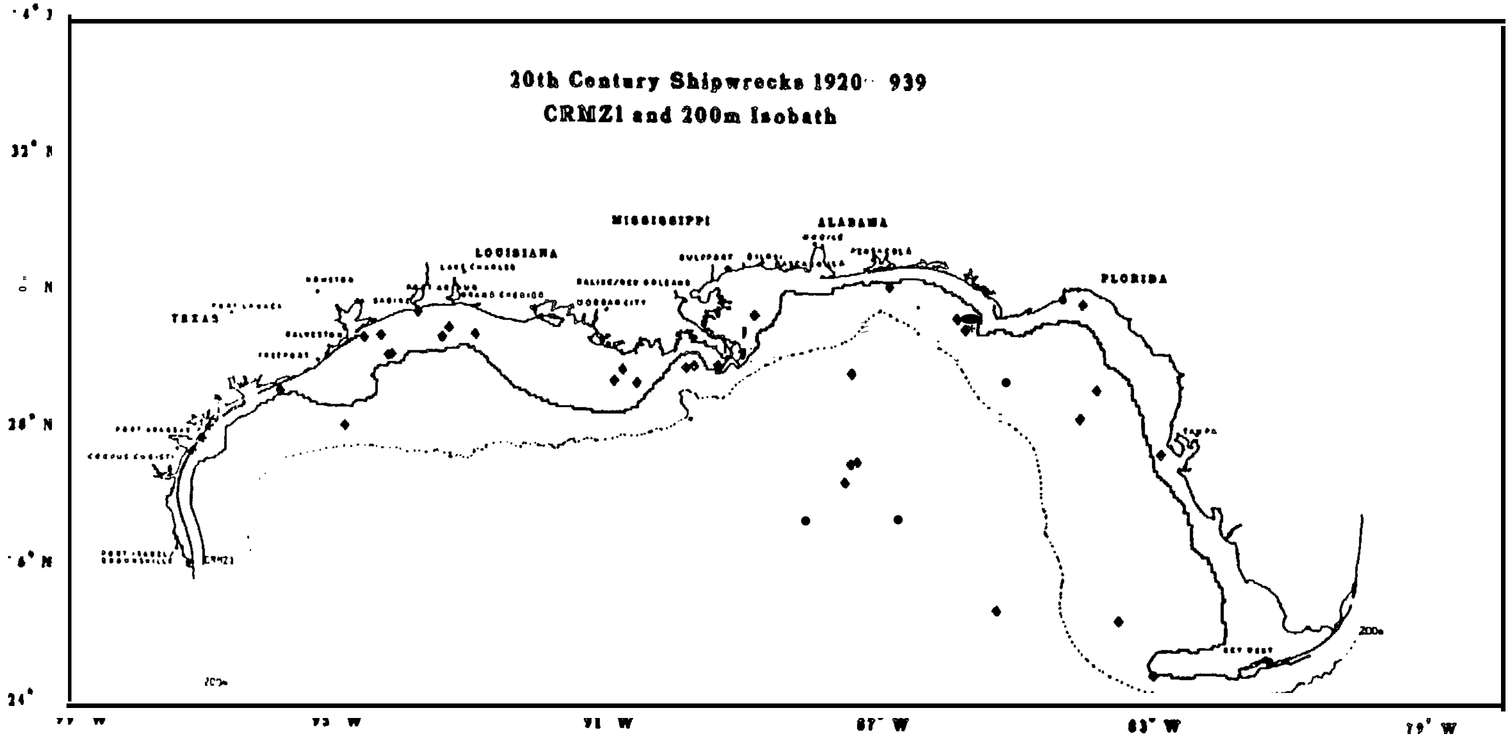


FIGURE II-34. Shipwreck positions, 1920-1939.

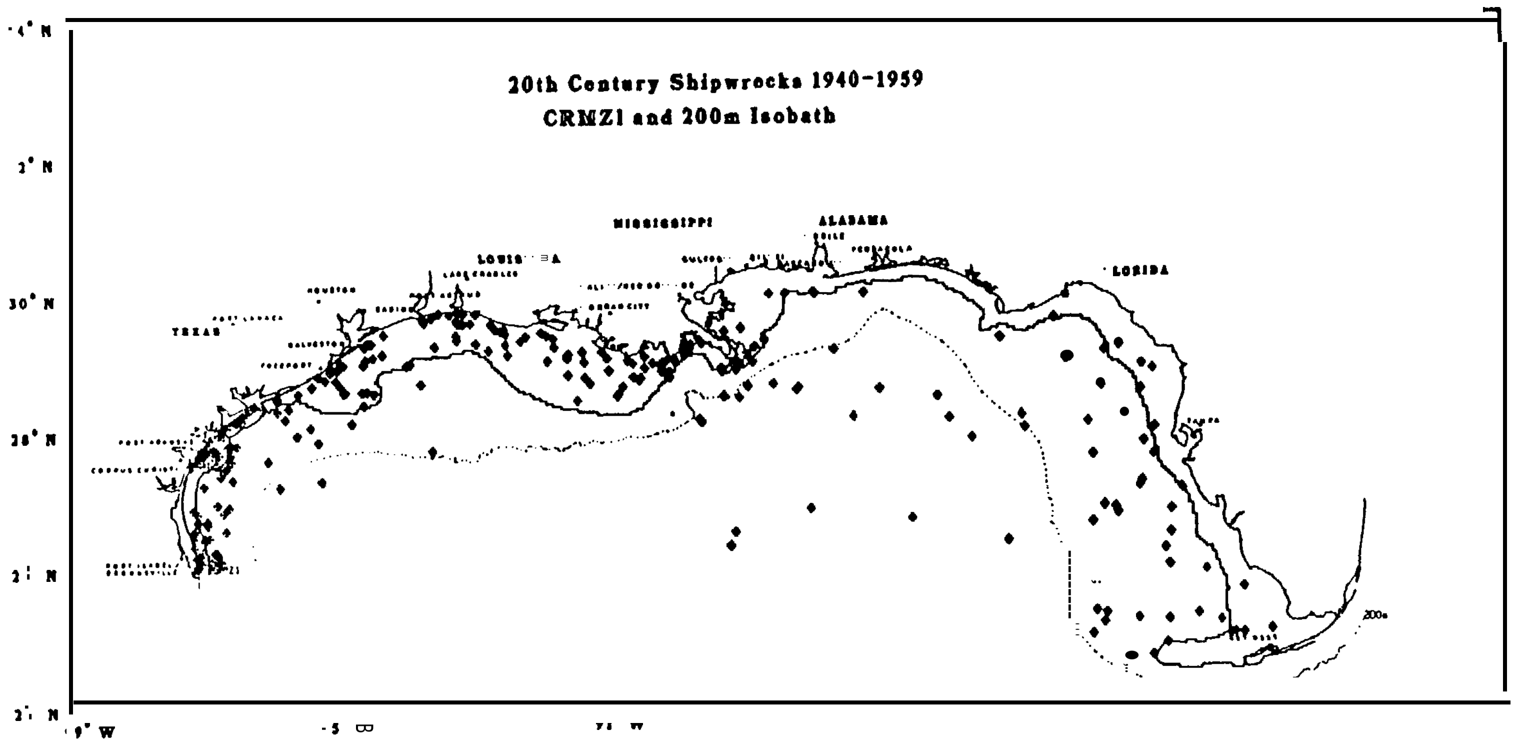


FIGURE II-35. Shipwreck positions, 1940-1959.

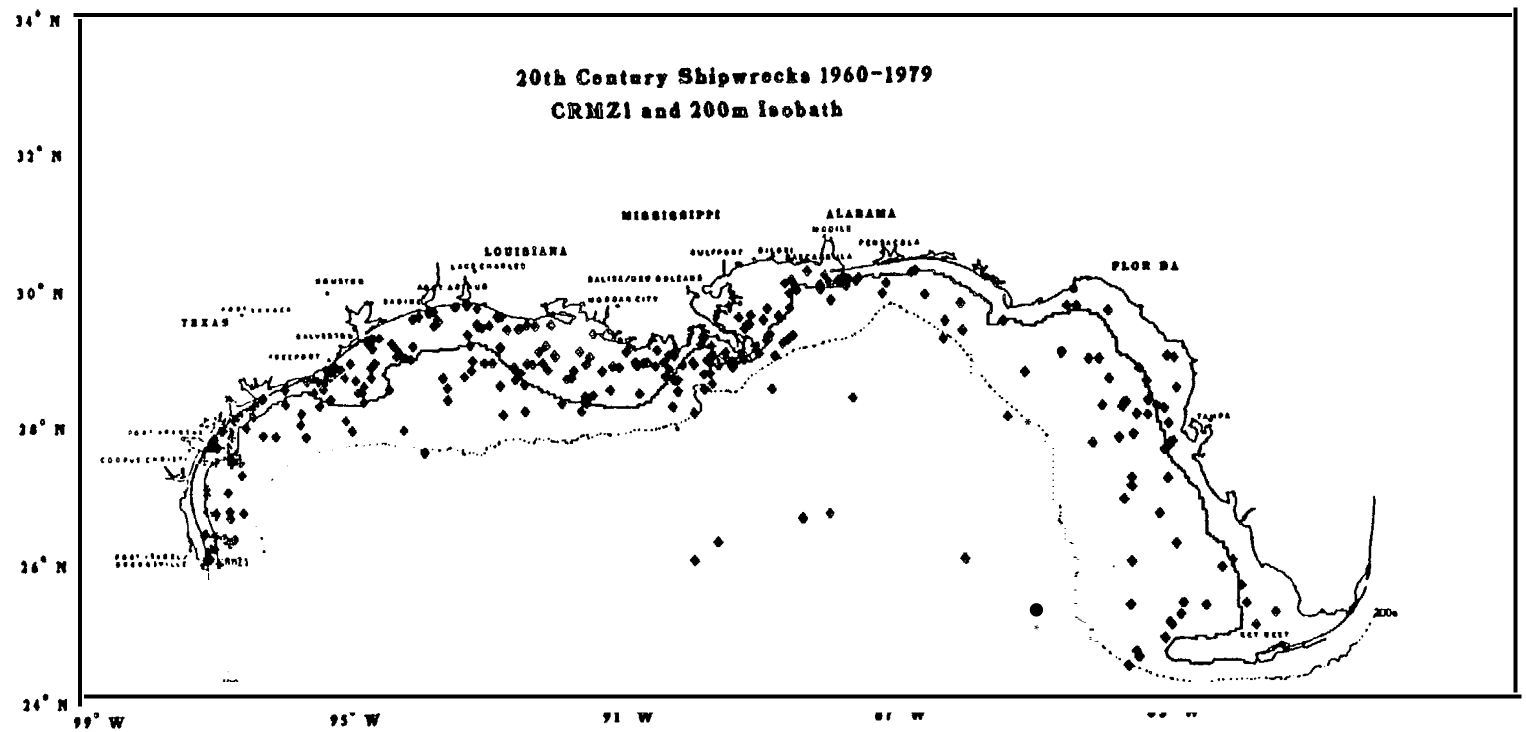


FIGURE II-36. Shipwreck positions, 1960-1979.

Table II-15.

SHIPWRECK FREQUENCY OVER TIME BY DECADE, 1500-1986.

Decade	Shipwrecks
1500-1509	0
1510-1519	0
1520-1529	7
1530-1539	0
1540-1549	4
1550-1559	10
1560-1569	1
1570-1579	3
1580-1589	0
1590-1599	4
1600-1609	2
1610-1619	2
1620-1629	13
1630-1639	3
1640-1649	3
1650-1659	0
1660-1669	0
1670-1679	2
1680-1689	10
1690-1699	2
1700-1709	9
1710-1719	4
1720-1729	2
1730-1739	40
1740-1749	10
1750-1759	11
1760-1769	20
1770-1779	17
1780-1789	9
1790-1799	10
1800-1809	20
1810-1819	38
1820-1829	41
1830-1839	85
1840-1849	196
1850-1859	89
1860-1869	186
1870-1879	149
1880-1889	178
1890-1899	126
1900-1909	240
1910-1919	367
1920-1929	259
1930-1939	76
1940-1949	267
1950-1959	541
1960-1969	678
1970-1979	367
1980-1986	53

Table II-16.

CHRONOLOGICAL TRENDS IN GULF SHIPWRECK DISTRIBUTIONS BY 50 YEAR PERIODS.

1500-1549: Losses reflect period of Spanish exploration of northern Gulf of Mexico

1550-1599: Distribution begins to show pattern of losses determined by flota routes. Losses off Texas are flota vessels wrecked by storm while on this route. Losses of Florida are likewise. The Straits area begin to take their toll.

1600-1649: The principal losses are still Spanish flota vessels. The 1622 hurricane losses in the keys are a significant portion of the shipwreck pattern for this period.

1650-1699: The pattern reflects the first French losses in the Gulf at Matagorda Bay in 1685. The remainder are Spanish losses.

1700-1749: The distribution shows the first major change in northern Gulf's shipwreck pattern. This is due to the French colonization of Louisiana and the increase in a similiar interest by the Spanish in Pensacola to balance the French.

1750-1799: 'The pattern of shipwrecks in the north-eastern Gulf is the result of two basic processes: colonization and commerce. The French and Spanish have reached the height of their maritime activity in the Northern Gulf of Mexico. The flotas end in the last quarter of this century.

1800-1849: The shipwreck distribution shows the extension of the colonization process to the north-western Gulf of area. Texas and Louisiana west of the Delta has port development at a significant level after the 1830's with Galveston, Brownsville, Freeport rising to importance.

1850-1899: The continued shift westward in the shipwreck distribution is offset by the principal ports of New Orleans and Mobile in the North-central Gulf area. The observed pattern is skewed by the extent of the Texas data for the period. Losses in the Straits continue as it is the major egress channel for inter-Gulf commerce. Eastern Gulf losses in the Civil War are under-represented in the Panhandle region. e.g. Apalachicola and Cedar Key,

SHIPWRECK DISTRIBUTIONS BY 20 YEAR PERIODS, 1900-1979

1900-1919: The pattern is fully modern with intra and inter-Gulf commerce developed between all major ports. The eastern area has Tampa growing as a port and major fisheries off the Panhandle and Florida Keys, The distribution of open-Gulf shipwrecks reflects the major commercial sea route to the Mississippi River and New Orleans.

1919-1939: The pattern for modern era is the result 20th century Gulf commerce in commodity goods e.g. oil and agricultural exports.

1940-1959: Two principal factors increase the number of shipwrecks off southwest Florida: fisheries and Tampa trade. For the northwestern Gulf it is singularly petroleum production in the offshore that cause Intra-Gulf routes to shift westward to Houston (cf. Figure I-I 6).

1960-1979: The major intra-Gulf, inter-Gulf routes axis are still (Present) east-west reflecting bulk cargoes movement from central/north-west Gulf ports. Losses increase in the north-western area exploration/production movement to the outer shelf.

9.1.4 *Spatial Analysis -Arithmetic Mean Centers (AMC)*

A **trend in the scatter plots is the aggregation of shipwrecks within the northern** Gulf with time. The arithmetic mean centers (AMC) were calculated for the shipwrecks within quadrants of 0.5 and one degrees. No attempt has been made to examine the variations in the aggregation of AMCS over time. The objective is to examine the presence or absence of aggregation at the most general level. Tables 11-17 and 11-18 summarize the data (Appendix 1) (Figures II-37, II-38, II-39, and 11-40).

9.1.5 *Spatial Analysis - Contour Plots and Cluster Analyses*

Figure II-41 is a contour plot of the one degree quadrant data using the graphic contouring package, DISSPLA (ISSCO 1976).

The value for each quadrant is treated as a point determination of shipwreck density. The general shape and size of areal concentrations is seen in this visual presentation.

Data from the shipwreck file were arranged into a matrix of lease block codes and numbers of shipwrecks. A cluster analysis with a flexible sorting strategy (Pimentel 1979) was used to construct the dendrograms in Figures II-42 and II-43. The Bray-Curtis index (Bray and Curtis 1957) was used as a measure of distance between shipwreck dates and lease blocks.

The main purpose of cluster analysis is to sort a previously unpartitioned heterogeneous collection of objects into a series of sets; e.g. one wishes to identify sets and allocate objects to those sets. A number of different clustering schemes are available. For this study, the clustering algorithm chosen was sequential and agglomerative. A sequential clustering process forms clusters in a regular stepwise manner and is much faster than "simultaneous" formation of clusters. Agglomerative clustering procedures begin with pairs of objects (e.g. ships, dates, etc.) and build up clusters. Divisive methods begin with the entire data set and divide it into subsets (Rohlf 1970).

The dendrogram of date similarity shows four distinct groups (Figure II-42). All of the 1900s and the 1850-1899 dates are grouped in one cluster while the remaining groups are not clustered together. This dendrogram groups together dates with the greatest similarity in number of shipwrecks within the same lease block location.

The matrix transpose (Figure II-43) separates into nine distinct groups. This dendrogram groups lease blocks with similar numbers of shipwrecks. These lease block groups were plotted to examine their spatial distribution (Figure II-44).

Three dimensional plots of latitude and longitude by date increment were generated for the nine groups derived from the cluster analysis of dates (variables) and lease blocks (observations) (Figure II-44). These figures provide a visual representation of the cluster analysis results.

These figures represent a view from about Brownsville, Texas in the southwestern Gulf of Mexico looking toward the northeast at an approximate viewing angle of 70 degrees above the vertical axis. Each cylinder symbol represents one or more shipwrecks within a specific lease block for a given date interval. Summary information is included below each plot which describes each group's characteristics. With the spatial data, the primary cause of dissimilarity between groups two, three, four, five, six and groups one, seven, eight and nine, is the number of ships in a lease block (high and low respectively). Additionally, the mean shipwreck date separates groups one, two, three, four, and nine from groups five, six, seven, and eight (early and recent respectively).

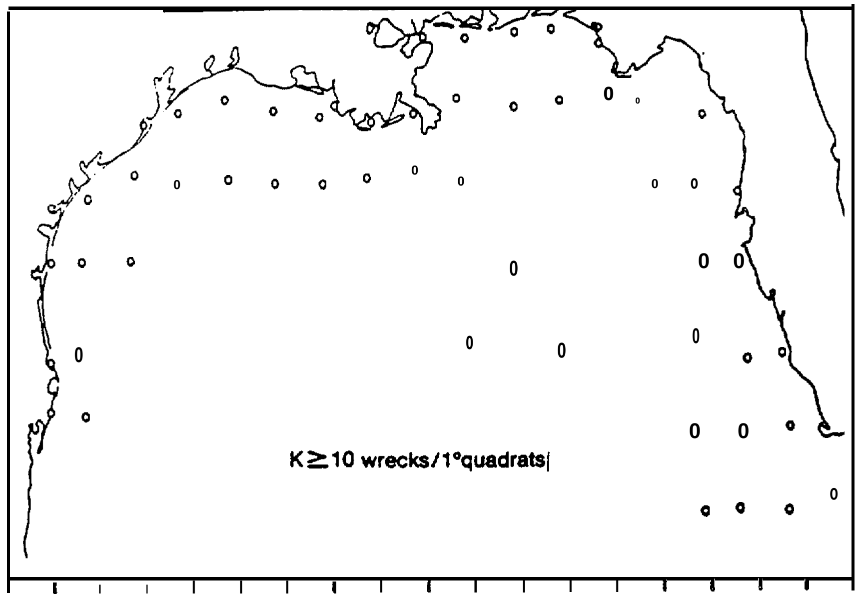


FIGURE II-37. AMC **for K≥1** O, **one degree quadrats.**

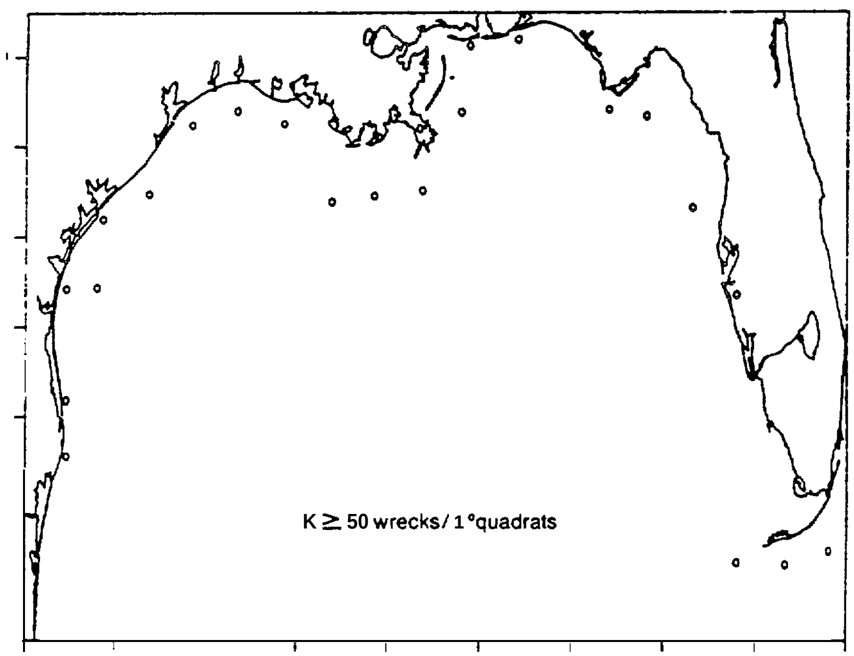


FIGURE II-33. AMC for **K≥50,** *one* **degree quadrats.**

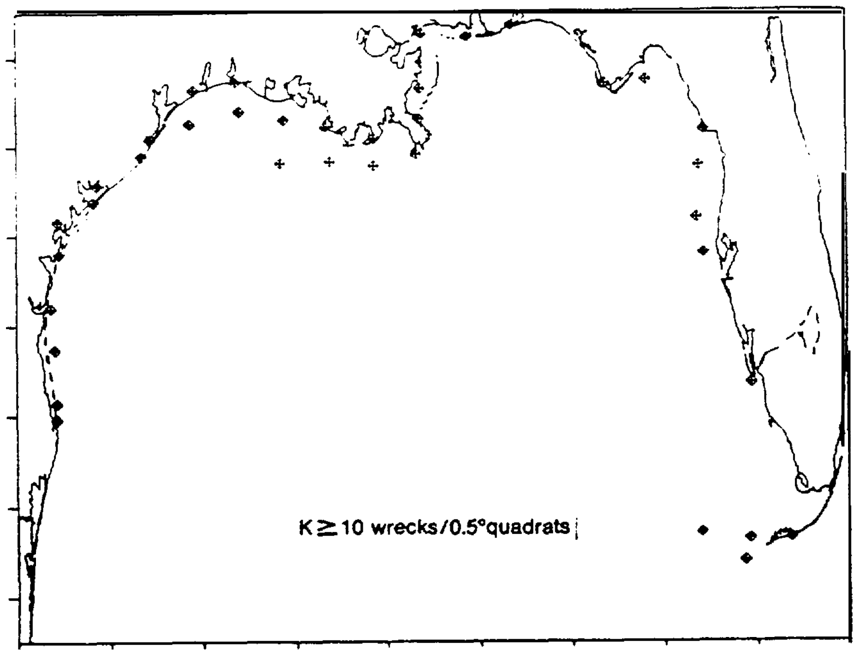


FIGURE II-39. AMC for K≥1O, 0.S degree quadrats.

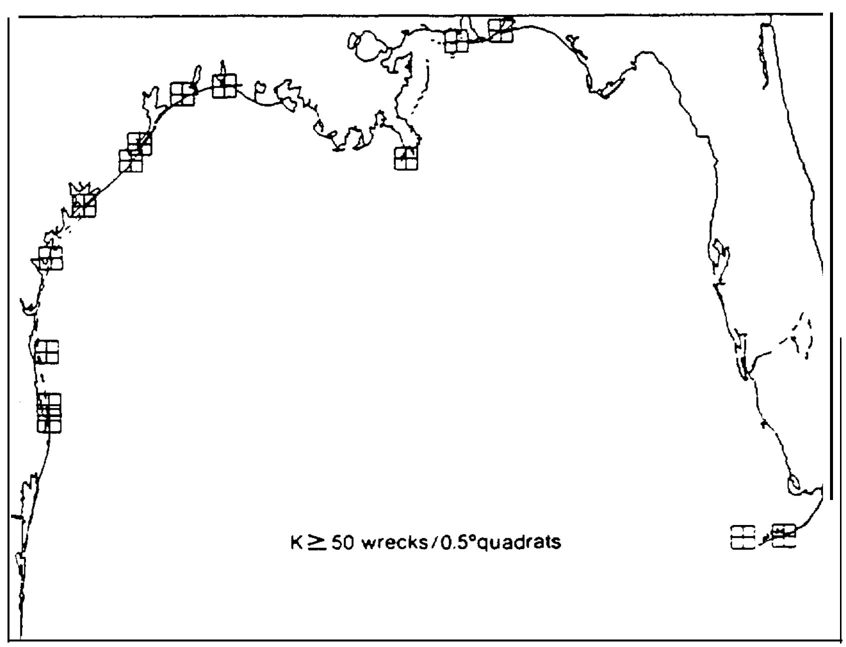


FIGURE II-40. AMC for K≥50, 0.5 degree quadrats.

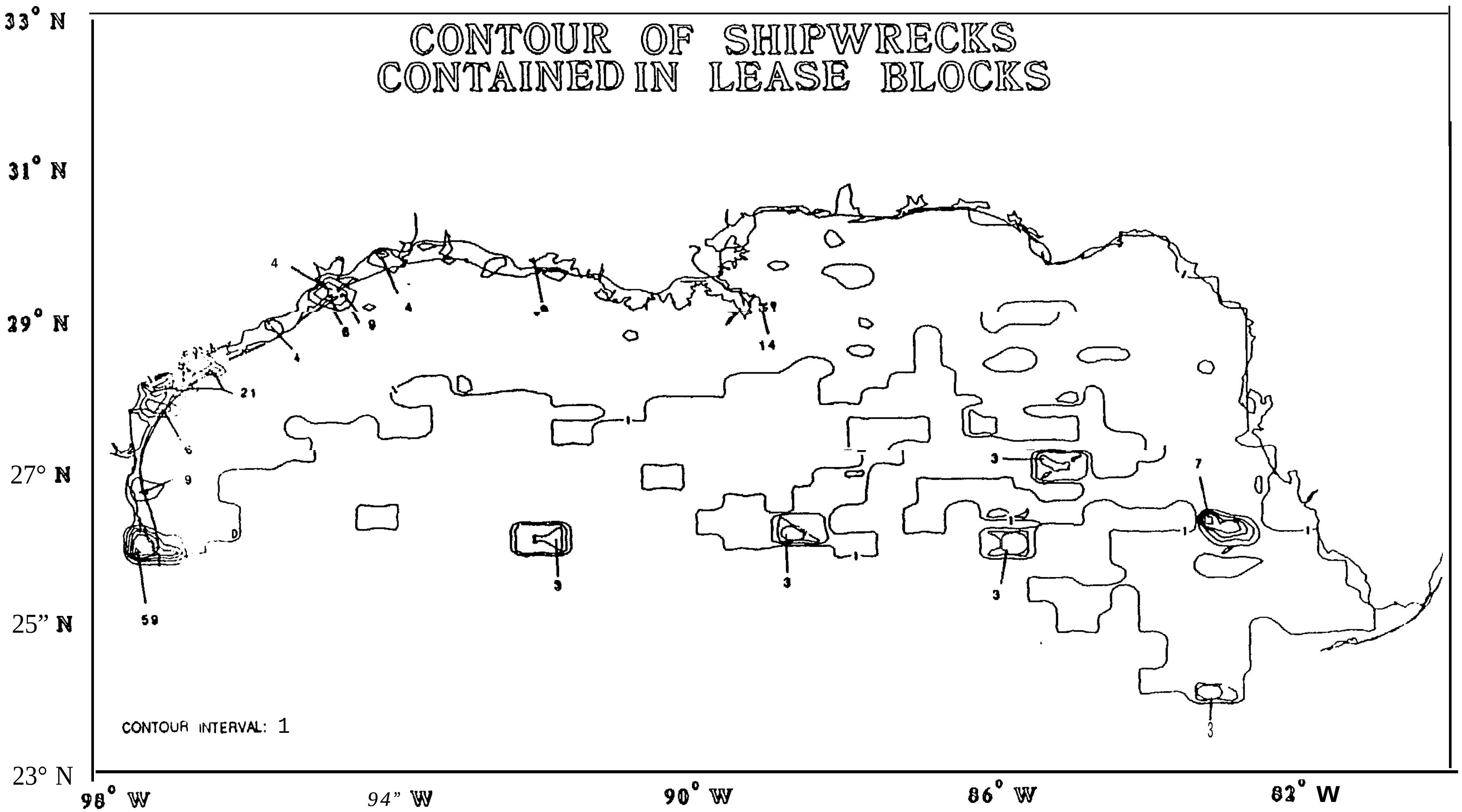


FIGURE II-41. Contour **plot of shipwrecks contained** In lease blocks.

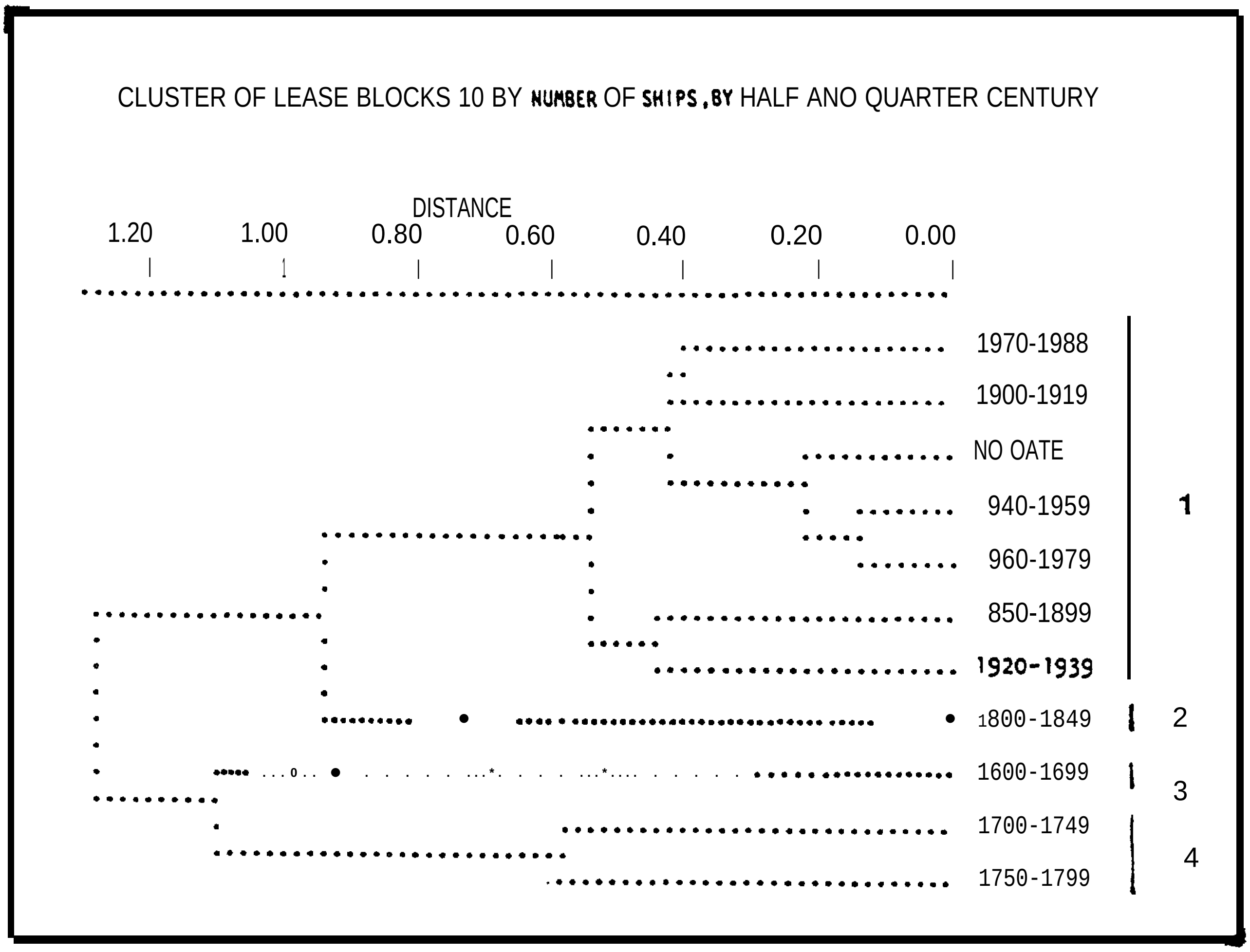


FIGURE II-42. Dendrogram of 50 and 20 year intervals.

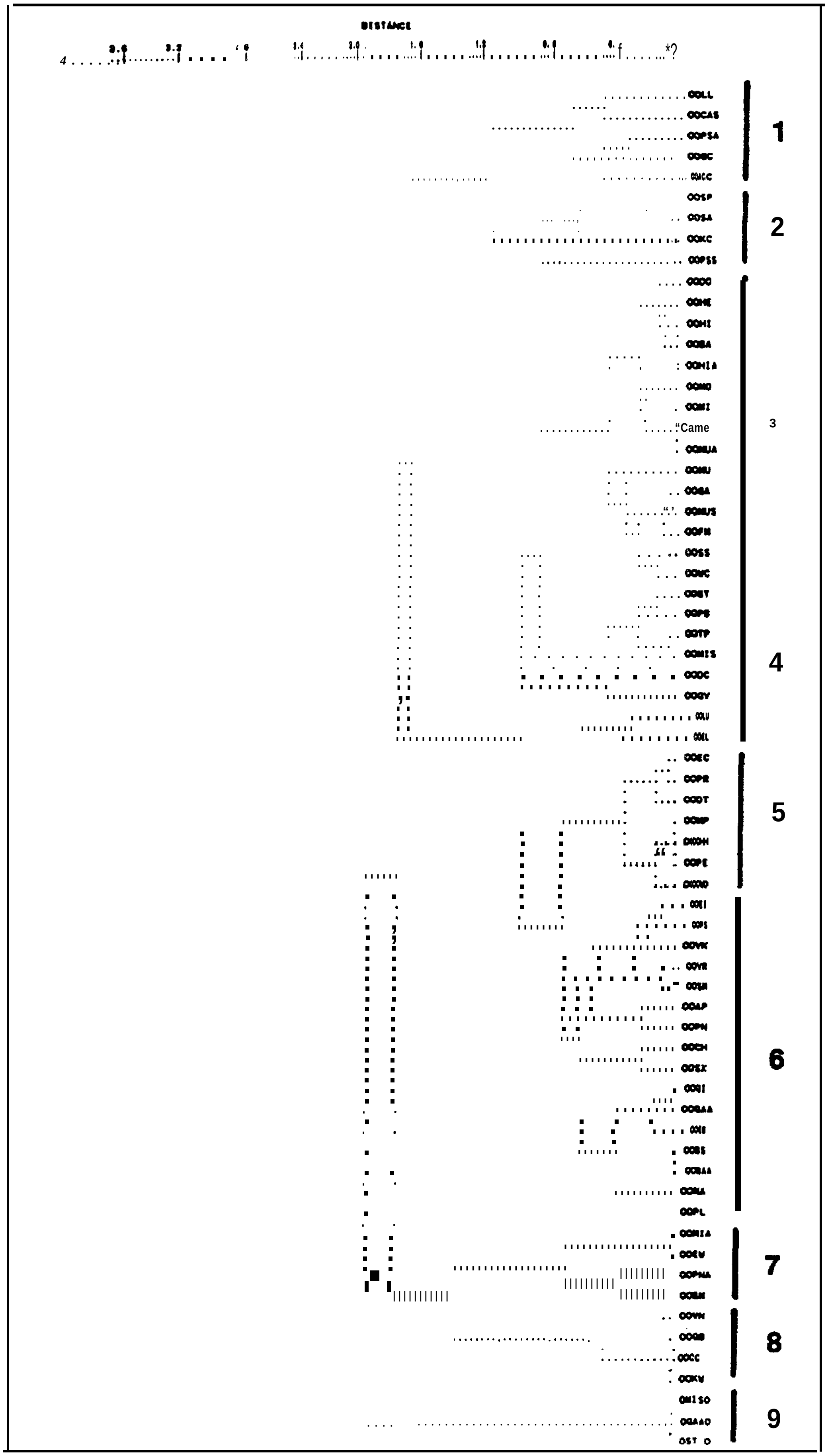


Figure II-43. **Dendrogram** of lease blocks.

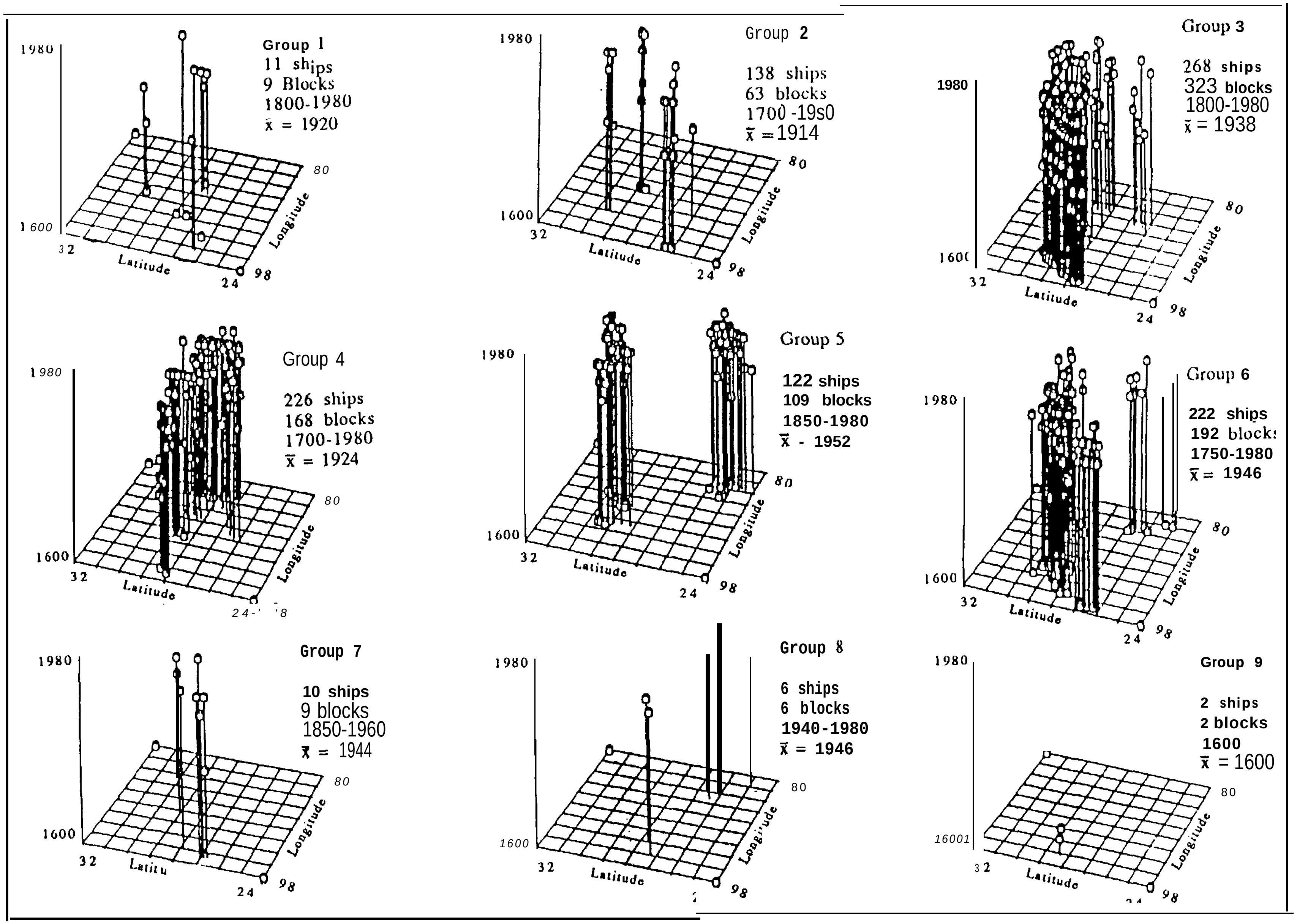


Figure II-44. Three-way plot of dendrogram lease block groups.

Table II-17.

AMC ANALYSIS: 1° (DEGREE) QUADRATS.

a) V = l : This result simply shows quadrats with reported shipwrecks. Little in the way of locational or spatial trends were seen and no plot is presented..

b) K ≥10: Here the criterium for assigning an AMC is that the quadrat must have ≥ 10 shipwrecks. What is interesting is a two-level spatial distribution of AMC's (Figure II-37). The inner row of points correspond to nearshore shipwrecks while the second, more seaward distribution, are deeper water shipwrecks. This distribution collapses with the increases of (n) as seen in the next step.

c) K ≥ 50: The distribution of AMC's follows that of the nearshore shipwrecks with little representation of the less numerous offshore losses (Figure II-38). This distribution closely approximates CRMZ1 as currently defined (MMS Visual No. 11).

Table II-18

AMC ANALYSIS: 0.5° (DEGREE) QUADRATS

a) K > 10: The distribution (Figure II-34) differs significantly from the one degree quadrat results. This reflects the effect of area analysis. That is larger size better reflects broad-scale pattern as smaller quadrats are sensitive to finer-scale patterning. What is interesting is the way the pattern more closely approximates one degree quadrat results of N≥50. The trend is shoreward off Texas, but more seaward of Western Louisiana.

b) K > 50: Here the distribution (Figure 11-40) collapses onto all the major port locations of the northern Gulf with the exception of Tampa, which may be an artifact of an under representation of data for the given area.

Group nine is the simplest projection of the dendrogram data as it is composed exclusively of 16th century shipwrecks. Group five as well as group six show a partitioning of shipwrecks into two sectors of the Gulf--The Keys and the west-central areas. Groups three and four contain shipwrecks of the central and east Gulf areas. Groups one, two, seven, and eight are best characterized as open Gulf losses.

9.2 Specific Factors and Shipwreck Patterns

In this study we examined five principal factors affecting shipwreck locations and patterns. These are: (1) historic shipping routes; (2) port location; (3) shoals, reefs, sandbars, and barrier islands; (4) ocean currents and winds; and (5) historic hurricane routes.

These factors do not account for all the shipwreck locations in the northern Gulf but reflect the most important elements in understanding the distribution of shipwrecks and developing explanatory models for shipwreck patterns.

The comparison of this data with the various distributional plots of the shipwreck data allows comparisons such as seen in Figure II-45 where similar patterns for shipwrecks and offshore oil development (Figure II-46) for the Louisiana and upper Texas coasts are observed.

9.2.1 *Intercorrelation of Study Factors* Affecting *Shipwreck Location* - *Factor* Analysis

Two separate factor analyses were conducted for shipwrecks and variables that relate to their distribution across various Gulf areas. The first analysis evaluates these variables versus sectors of the Gulf coastline as defined by DeWald (1980). The data are broken down chronologically so that temporal trends or correlations may be detected in the analysis. The second analysis used a matrix of fewer cases, based on larger Gulf areas, and variables less sensitive to chronological variation but perhaps sensitive to the other associations in the data.

9.2.1.1 Analysis 1: Chronological Factors

This matrix is composed of seven variables (four time periods, age of ports, ports, storms) and 26 observations (Gulf areas) for each variable (Appendix J; Table 11-19). A principal component factor extraction method was utilized. The factors were evaluated for independence and variance. The program used was STATVIEW (Abacus Concepts 1986).

Five variables were used which measure shipwreck frequency in six periods. Data **for** the 16th century were merged with that of the 17th century because of the low number of shipwrecks known for these periods. Further, it is assumed that the processes underlying the patterns were similar for both periods.

The data for the 19th century was partitioned because processes responsible for shipwreck patterns changed more rapidly and the data were scaled accordingly. The results of the factor analysis appear in Appendix J and our interpretation of these results are:

1. Three factors were defined (Table II-19);
2. These factors are largely independent of one another; (1.454 vs 1.468);
3. The variance is equally divided between these three factors (0.43, 0.31, 0.26);
4. **Factor 1 is characterized** as an association of 16th, 17th, and 18th versus 19th and 20th century wreck locations. It represents a demographic factor;
5. Factor 2 is characterized by a moderate association of variables representing 19th century shipwrecks and port development; and
6. Factor 3 associates port and storms. The linkage is not compelling. Ports seem to be more strongly associated with wreck frequency than with the number of

years the port existed. The proportion of the variance explained by this factor is low.

9.2.1.2 Analysis 2: Areal Factors

This matrix is composed of six variables (hurricanes, ports, routes, hazards, energy, wrecks) and 1 O cases (periods) per variable (Table II-20)(Appendix I). The methodology differs from the previous analysis. Larger scale areas of the Gulf are compared with the presence of hurricanes, ports, traffic routes, hazards, and energy zones in relation to shipwreck frequency. Table 11-20 shows the data used in the analysis along with additional tables and associations. Table II-1 2 illustrates the values used to calculate the shipwreck frequency for the areas. The hurricane frequency is taken from Tannehill (1956) with little alteration. The variable "routes" represents the number of periods with major inter or intra-Gulf routes present; "hazards" represents major reef, shoal, or other hazards. The results of the factor study are as follows:

1. Two factors were identified. This was seen when restricting the program to this number of factors and allowing the program to determine the number of factors independently;
2. The factors are not strongly intercorrelated although the same cannot be said of the variables. The matrix sampling efficiency (MSA) is low (0.498) reflecting the number of composite or interrelated variables. Elimination or redefinition of some of these variables could raise the MSA although the value is not significantly below 0.50 which is the value commonly used to evaluate the sampling adequacy;
3. The orthogonal solution seems a good approximation when compared to the unrotated or oblique solution. Following the oblique solution (varimax), we see a proportionate accounting of the variance 0.63 for Factor 1 and 0.37 for Factor 2 ;
4. Factor 1 is interpreted as depicting a strong association of shipwrecks to routes and hazards (0.698; 0.672); and
5. Factor 2 associates shipwrecks and ports. Our first inclination is to call this the "ports" factor,

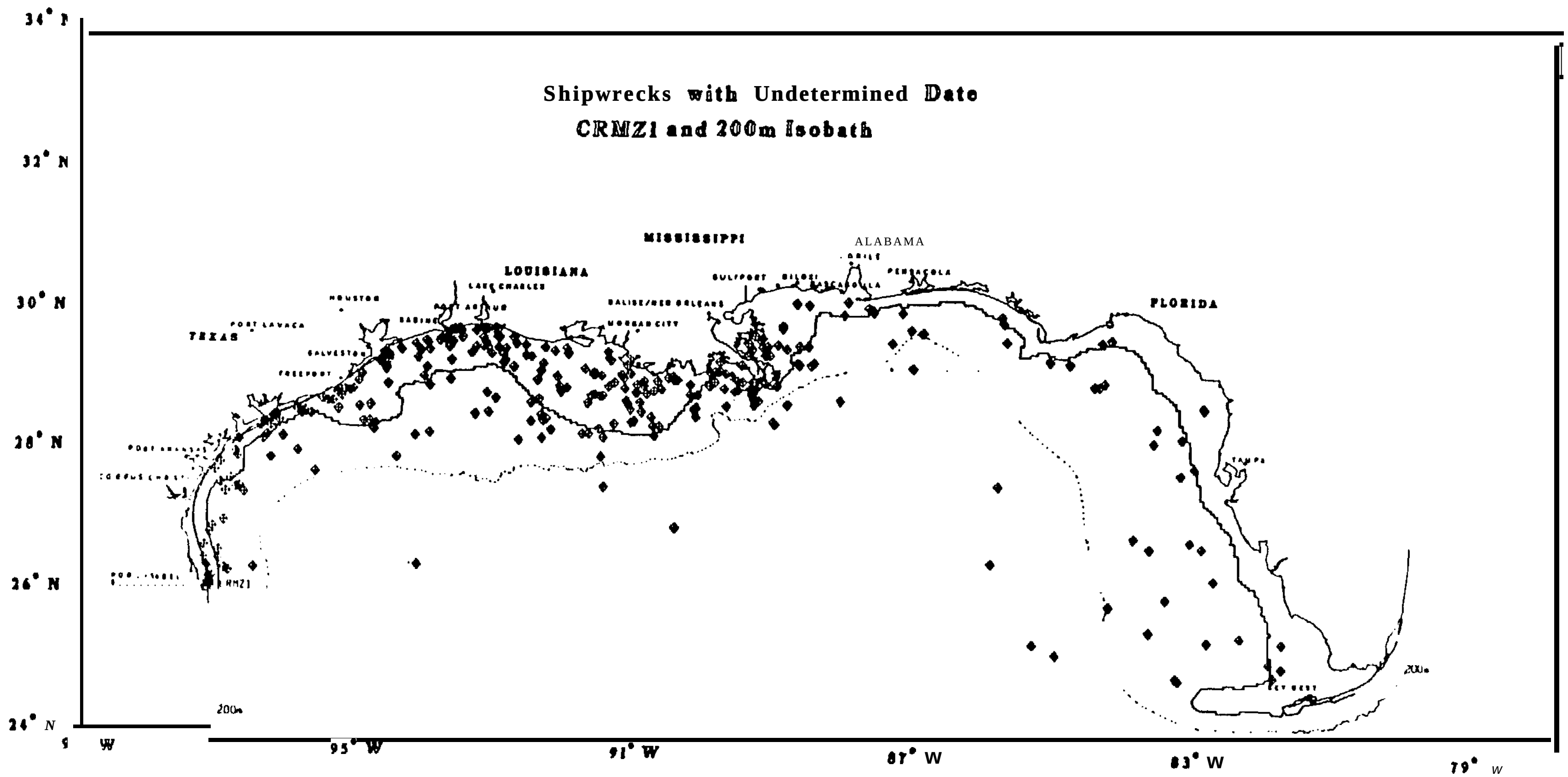


FIGURE II-45. Shipwreck **positions, year** unknown,

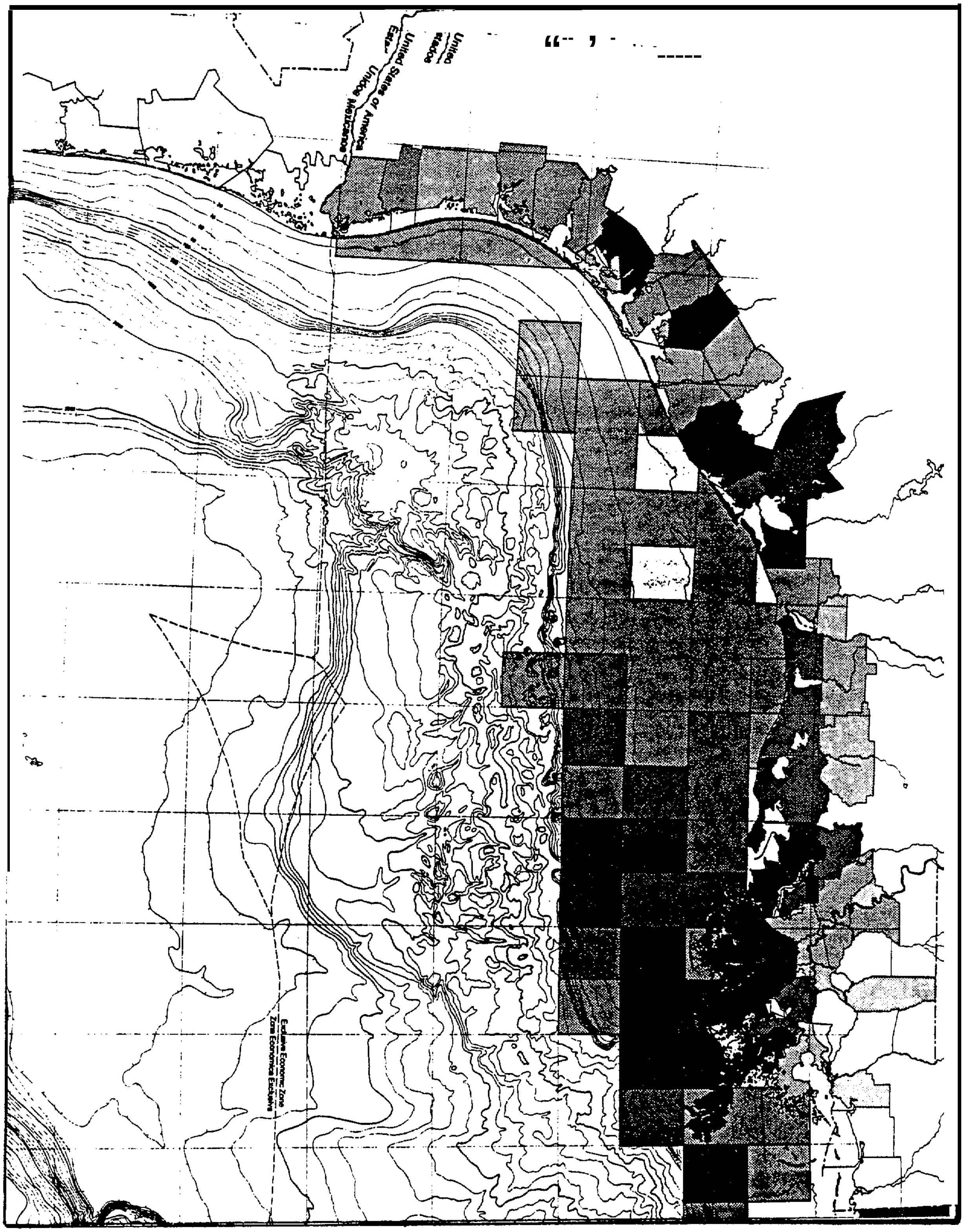


FIGURE II-46. Areas of 011 and **gas activity.**

Table II-19.

FACTOR ANALYSIS - CHRONOLOGICAL FACTORS.

a. Chronological Variables

	Wrecks 20th C.	Wrecks 19th C.	Wrecks 18th C.	Wrecks 17-18th C.	Age Oldest Port	Ports,Major	Major Storms	Column 8
1	13	38	0	8	149	1	13	•
2	10	57	0	4	88	1	8	•
3	11	42	0	0	142	1	15	•
4	47	69	0	2	144	1	10	•
5	61	64	0	0	153	1	9	•
6	102	117	0	0	167	1	12	•
7	30	29	0	0	148	1	9	•
8	0	0	0	0	0	0	9	•
9	0	0	0	0	0	0	12	•
10	24	0	0	0	138	1	7	•
11	126	0	0	0	270	1	26	•
12	21	12	0	0	270	1	26	•
13	57	42	0	0	118	3	9	•
14	39	23	12	0	288	1	21	•
15	30	0	0	0	168	1	3	•
16	0	0	0	0	0	0	12	•
17	15	11	0	0	34	1	9	•
18	8	0	0	0	8	0	8	•
19	8	0	0	0	0	0	14	•
20	8	0	0	0	0	0	13	•
21	53	0	8	0	113	1	21	•
22	0	0	0	0	0	0	10	•
23	10	0	0	0	148	2	7	•
24	11	8	0	0	0	0	6	•
25	22	14	43	15	166	1	12	•
26	156	57	87	29	8	0	15	•

b. Chronological Factors

Oblique Solution Reference Structure-Orthotran/Varimax

	Factor 1	Factor 2	Factor 3
Wrecks 20th...	.716	.511	.414
Wrecks 19th,..	.387	.777	-.084
Wrecks 18th...	.955	-.001	.089
Wrecks 17-...	.956	.023	.016
Age Oldest P...	-.07	.617	.71
Ports,Major	-.162	.797	.206
Major Storms	.188	-.001	.938

Table 11-20.

FACTOR ANALYSIS - AREAL FACTORS.

a. Areal Variables

	Hurricanes	Ports	Routes	Hazards	Energy	Wrecks
1	10	1	2	0	3	3
2	10	2	2	0	3	12
3	10	6	2	0	1	27
4	5	2	3	3	2	15
S	15	4	3	2	2	6
6	13	1	3	2	3	4
7	4	0	3	0	0	6
8	4	2	3	0	2	6
9	4	1	4	S	0	4
10	4	0	4	5	0	17
11	•	•	•	•	•	•
12	•	•	•	•	a	•
13	•	•	•	•	•	•
14	•	•	•	•	•	•
1s	•	•	•	•	•	•

b. Areal Factors

Oblique Solution Reference Structure-Orthotran/Varimax

	Factor 1	Factor 2
Hurricanes	-.675	-.067
Ports	-.097	.707
Routes	.698	-.152
l-hazards	.672	.001
Energy	-.892	-.39
Wrecks	.488	.94

10.0 SUMMARY AND CONCLUSIONS - TASK I

Determining spatial patterns of shipwrecks in the Gulf of Mexico does not explain the causes for these patterns. These factors are not always independent. For example, increased frequency of shipwrecks along trade routes does not explain why the vessels were lost, only why they were there in the first place. Factors such as poor seamanship, poor navigation, scuttling, explosions, and fire cause shipwrecks. The maritime insurance system can also be a causal factor in intentionally wrecking vessels, but it probably claims only a relatively small percentage of Gulf ships (James Parrent 1986, personal communication). These lessser factors and the principal ones detailed in this study determine a vessel's safe journey or unfortunate loss.

An interesting aspect of the analyses conducted on the data in this study shows an increase in the number of losses over time. This contradicts conclusions in the CEI study (1977) where the peak for shipwreck losses was expected to lie between 1880 and 1910. New data suggests that shipwreck loss continues to increase through the 20th century. This fact is somewhat surprising if one assumes, like the CEI investigators, that improvements in the technology of ship design, the use of diesel engines, and better navigational tools would reduce the number of ships lost over time. However, the rate of shipwrecks actually increases because of improved technology. Improved technology may allow more vessels to be exposed to risks that early mariners would avoid because of recognized shortcomings in their ships or navigational aids.

Important natural factors that influenced the distribution of shipwrecks are storms, historic hurricanes, and the weather fronts called "northers." At the outset of the CEI study northers were considered under the larger category of winds, currents and energy zones. The normal wind patterns were not representative of seasonal storms. Sailing ships used the prevailing winds in their travels. These winds influence nearshore currents whereas the Loop Current and its eddies dominated the central Gulf and Straits of Florida. Storms broke these normal patterns and drove vessels into nearshore hazards or caused them to founder in the open sea. Examples given in this report (SAN MIGUEL (1551), L'ADOUR (1722), EL NUEVO CONSTANTE (1766), Solano's fleet (1780)) are representative of the direct casual nature of seasonal storms in the loss of ships in the northern Gulf.

Over 16 percent of vessels involved in the Spanish Carrera fleet suffered loss due to storms (Chaunu and Chaunu 1955). As that landmark study evaluated over 11,000 sailings this percentage for the first century and half in the Gulf's maritime history is reliable. Our own correlation of historic hurricane data with the MVUS and BAR shipwreck files show a percentage of storm related losses to be 16 and 9.1 percent respectively.

There is a correlation between large hurricanes and shipwrecks for the specific years of 1622, 1733, 1780, 1886, 1900, 1915, 1919, 1928, 1944, 1947, and 1961. For eight reporting periods (31 years) in the MVUS data (1945-1976) we found that 16 percent of losses could be associated with tropical storms. For 14 historic hurricanes ranging from 1722-1981, we found a total of 146 verifiable ship losses or an average of 10 per storm. The correlation of individual storm paths and vessel losses is difficult because reporting practices do not list the hurricane as a cause, but report the ship as "foundered," "stranded," etc. Many of the vessels assigned to various storms were made on the basis of the simultaneity of location for storm and vessel on a given date. A general association is seen between storm frequency and the occurrence of shipwrecks, although the highest hurricane frequency areas do not have the highest occurrence of shipwrecks.

Another factor in the distribution of Gulf shipwrecks is the 307 km reef and shoal complex of the Florida Keys, Marquesas, and the Dry Tortugas. The convergence of winds, current, reefs, and storms make the Straits of Florida the most hazardous area for ships that exit or enter the Gulf. Charlevoix (1734, 1766) recognized that if a sailing vessel sailing east deviated half of a degree north or south, it was at the mercy of counter currents and the west-blowing trades (Figure II-16).

Westbound vessels ran the hazard of either the northern shore of Cuba or the reefs if they made for the countercurrents that ran close to these areas (Figure 11-19). The advent of steam made the journey more timely and predictable, but the distribution of late 19th and 20th century shipwrecks still underscores the high probability for wrecks in these regions.

The Chandeleur Islands east of the Mississippi have claimed a large portion of maritime traffic. This is associated with the development of coastal traffic from the early 1700s to the present day. It underscores the importance of New Orleans as the major historic port of the northern Gulf since the 18th century.

Winds and currents during the 16th through the 19th centuries made westward journeys easy but necessitated tacking or sailing off the wind in eastward crossings of the Gulf. The pattern for the winds varies from easterly in winter to south southeast for summer. To take advantage of the summer wind regime meant the sailing vessels from New Spain, Terra Firme or the Caribbean sailed northeasterly courses for much of their journeys before turning southeastward to the Florida Straits. As a result, vessels ascribed to routes which allowed them to take advantage of easterly flowing currents. With the coming of steam powered vessels and other changes such as colonization of the northern shore, this pattern was significantly modified.

Coastal traffic took advantage of the coastal currents in the southeast and northwest Gulf and winds in the central and north Gulf. The vessels risked the hazards of the shallow coasts when they traded the safety of deeper water for faster voyages by following coastal currents,

In summary, the patterns for Gulf shipwrecks are the result of economic decisions involving maritime commerce. The mariners used the winds and currents in the Gulf to chart the sailing routes we observe in historic records. This is seen in the change from the earlier period pattern of shipwrecks when compared to later periods. The Spanish lost ships principally at the Straits, not because of a poor reading of currents or winds, but to anomalies of weather (e.g. northers or hurricanes). Less frequently they made errors in navigation that resulted in a shipwreck. As a determining cause in shipwreck patterns, winds and currents must be viewed as secondary.

The probability for shipwrecks along the Gulf increased with the development of commerce. Commerce followed the colonization of Florida, Louisiana and Texas. After the turn of the 18th century, this development proceeded with France, Spain and Britain exchanging roles as their global fortunes changed. With the Anglo-American settlement of the northwest Gulf coast in the mid-1 9 century the picture was complete for maritime commerce. The entrances to harbors became high probability zones developed for shipwrecks .

Changes in the late 19th and 20th century shipping routes increased the observed frequency of shipwrecks in the open waters of the eastern Gulf (Figure II-47). The patterns for this later period are distinctly different for the west and east portions of the northern Gulf. The western Gulf has higher probability zones along and near shore, while the eastern Gulf has an incidence of shipwrecks in the open sea that is more than double that of the West (2.5 versus 5.4).[5] The reasons for this increased frequency are not completely understood. Traffic patterns are the most likely reason for the increased frequency of vessels exposed to the risks of storms and stranding. What is also of interest is the validity of hindcasting the same probability for vessel losses throughout earlier periods where sailing commerce was known to concentrate in this part of the Gulf. The question is an open one, but historical similarities in traffic pattern and frequency are not supported by the results of our factor analysis studies.

While the correlation of shipwreck sites to sailing routes is difficult, we have observed in our factor analysis that the association in the distribution of shipwrecks and the location of sailing routes for a given period are linked. Sailing routes were important in both a navigational and strategic sense. During the Spanish era of exploration these routes were

[5]Calculated using shipwreck frequencies per 10 quadrats, see Appendix 1.

PERIODS	PORTS	OPEN SEA	CHANNELS	COASTAL
16th /1 7th	0	.1	.5	.34
18th	.03	.16	.65	.17
19th	.48	.16	.25	.16
MOD	.32	.24	.19	.25

FIGURE II-47. Matrix of shipwreck probability.

defined by trial and error. The early Spanish navigator was restricted to a few principal routes determined by the Westerlies outbound to the New World and the tack against them using the Gulf Loop Current to reach the Gulf Stream. Exits from the Caribbean existed at either the Mona Passage (between Hispanola and Puerto Rico) or the Windward Passage (between Hispanola and Cuba). For the Gulf, Tierra Firme ships sailed the Yucutan Channel and the Straits of Florida, or a great arc for New Spain fleets from Vera Cruz, to near the mouth of the Mississippi River and southeast to the Straits. It is this later route that has the greatest significance for all periods in the Gulf during this age of sail.

We see a peak value for the occurrence of shipwrecks associated with ports in the 19th century (Figure II-47). For the 16th and 17th centuries losses are high given the lack of navigational aids, vulnerability to storms, and known piracy and warfare. This frequency increases for the 18th century for most of the same reasons as well as with the increase in ports (Figure II-49). In the 19th and 20th centuries, with improvements in navigational aids, ship design, and losses at ports, shipwrecks continue to be higher than in other areas, except the Straits of Florida (Figures II-48 and II-49). An explanation of the frequency of shipwrecks may be the direct result of a ship coming to port where an entrance bar lies. Such a pattern is seen at major port entrances.

Other longshore bars or off headlands may explain the occurrence of wrecks in shallow waters, Strandings are the result of encountering these hazards. A marked example of a treacherous shoal area is that off Cape San Bias (Figure 11-19). This shoal area has claimed a proportion of shipwrecks over that seen for the Gulf as a whole and is demonstrated in the distributional plots and the plot of the AMC's (Figures II-37 through 11-40).

10.1 Pattern and Distribution of Shipwrecks

The number of ships lost in the open sea versus those lost nearshore were discussed by Muckelroy (1978), Bascom (1976), CEI (1977), and Marx (1971). Marx estimated that approximately 98 percent of all shipping losses in the western hemisphere prior to 1825 occurred in less than 10 m of water. CEI's authors follow this proposition when developing the CRMZ1. Muckelroy suggested that the 10 m boundary probably underestimated the potential for deep-water archaeology. Bascom concluded from a study of 19th century losses at Lloyds of London that about 20 percent of all sinkings occur away from the coast. This figure probably better approximates the correct order of magnitude for all sinkings in the open sea at any period. The data in this study support Bascom. An inspection of our shipwreck distribution plots shows that 75 percent of shipwrecks occur in nearshore waters and the remainder in the open sea (Figure II-47).

Knowing shipwreck locations can sometimes increase the reliability of predicting other shipwreck locations. While recognizing that under reporting of losses in earlier periods exists, recognizing patterns must also include some understanding of historical processes that underlie patterns. Alfred Kroeber (1948) defined pattern recognition as "a rough plan of convenience for the preliminary ordering of facts awaiting description or interpretation. Interpretation requires a move to process those factors which operate either toward stabilization and preservation, or toward growth and change."

Kroeber, as an anthropologist, was speaking principally of cultural patterns and their stability, but it is clear such processes that operate on shipwreck patterns are the result of changes in the cultures of a particular time. Following Kroeber, we observe that shipwreck patterns persevere or change through time and space as a result of underlying cultural processes. We must conclude that processes underlying shipwreck patterns for the northern Gulf have changed over time. If processes, for a particular period are stable, then the pattern for shipwrecks shouldbe consistent for that era if our first assumption concerning under reporting is valid. To attempt to predict shipwreck locations between periods such as those of the Colonial times (17th - 18th centuries) using 19th century distributions seems unwise given the results of our factor analyses.

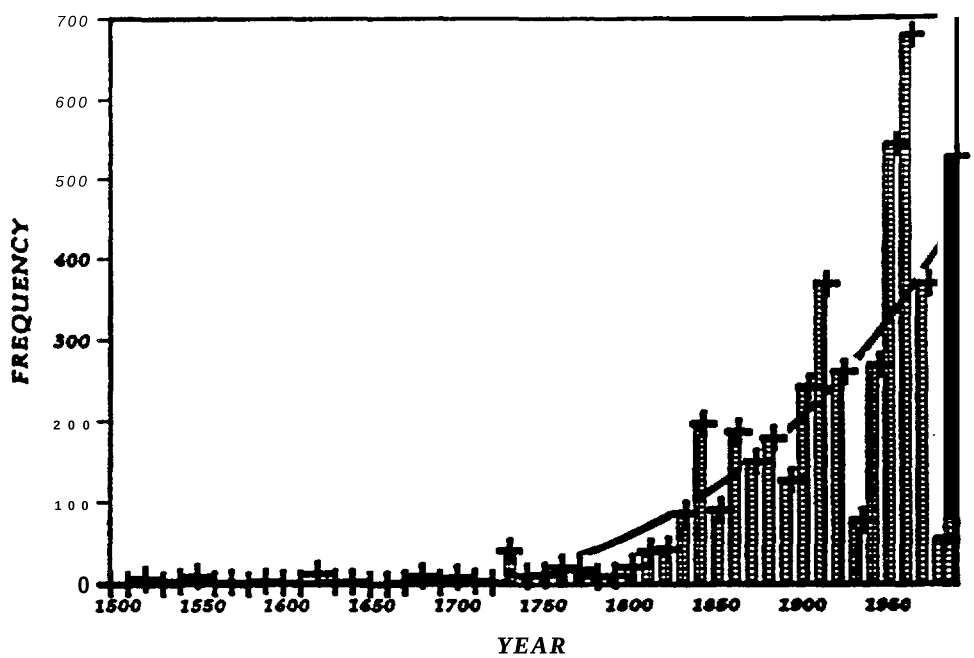


FIGURE II-48. Shipwreck frequency by decade.

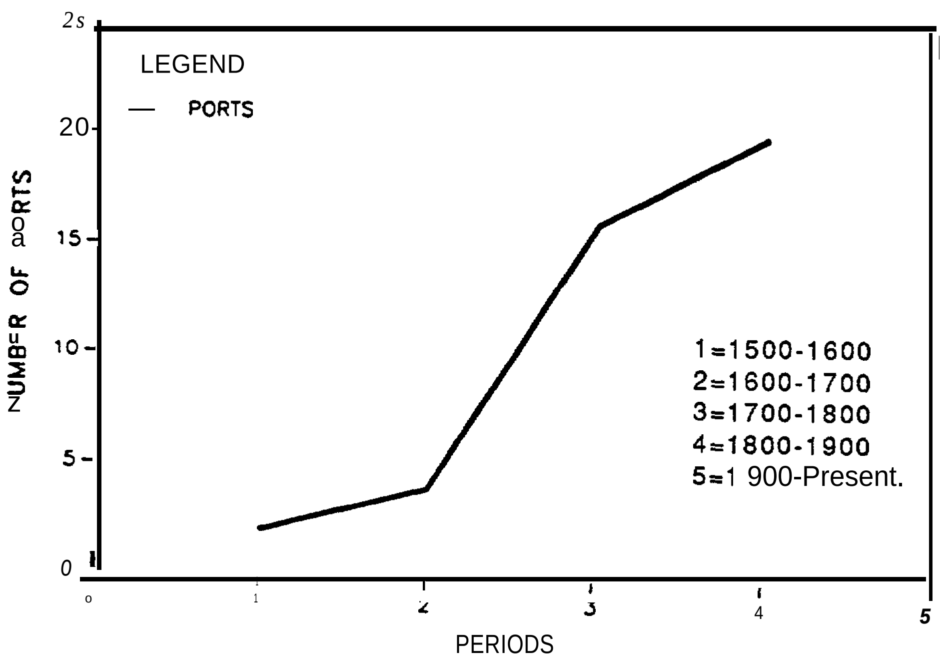


FIGURE II-49. Port development . northern Gulf of Mexico.

10.2 Point patterns, probability distributions, and processes

Settlement studies, such as one by Hudson (1969), considered a spatial process that led to clusters. His theory was that patterns were produced in three stages: (1) an initial stage of colonization by individual settlements or small groups of settlements; (2) a second stage of spread outward from these initial centers; and (3) a final stage moving toward a regularity in spacing and overall density. Such a model describes the Gulf's shipwreck data although distinctions must be made in the specific type of spatial diffusion.

Hudson's model and other models derived from biological analogues (Pielou 1969) ignore historical factors common in cultural processes. Outward diffusion from an initial settlement may be uniform to the point that it is constrained only by environmental factors such as availability of food, water and space. Pattern development for ports in the Gulf of Mexico is different.

Here the placement of ports is constrained by environmental factors (depth of water, winds, currents) as well as historical ones (communication, political and economic motives). A classic example of factors underlying the spread and placement of ports is early 18th century Pensacola. It was "refounded" as a direct response to the French placement of Mobile. The French, in turn, founded New Orleans in order to establish direct communication with her northern territories and to exert pressure on Spanish Texas (Weddle 1987).

The number of shipwrecks follows the number of ports founded. Their location follows that of routes between the ports. In French Louisiana, shipwrecks increased to a level reflecting the economic commerce the colony could support. After Louisiana became an American possession, the population increased along with the number and size of ports. Consequently, shipwreck frequency increased. Larger centers, such as Houston and New Orleans, have shifted patterns toward those portions of the Gulf where traffic to and from these ports is heaviest (Table II-3).

10.3 Preservation and Shipwrecks

The potential for shipwreck site preservation is another important consideration in the overall analysis of the CRMZ1. If an area with a high potential for historic shipwrecks lacks the potential for preservation, that area may not need to be included within the boundary of the CRMZ1. An example of an area with negative environmental factors for site preservation is the region at the mouth of the Mississippi River. By historic accounts, it was an area of high ship concentration. The tremendous sediment deposits off the Mississippi Delta militate against finding a shipwreck in that area due to sediment dynamics. If, by chance, a site survived these natural forces, it would be covered by sediments of a depth that would insulate it from discovery.

Examples of information derived from shipwreck preservation studies on the OCS CRMZ1 are: Clausen and Arnold (1975); Arnold and Weddle (1978); Hole (1974); Arnold and Hudson (1981); and Pearson, et. al. (1981). From this we derived a measure of the relative probability for shipwreck preservation in various areas of the northern Gulf of Mexico (Figure 11-50). Ships falling on areas of moderate to high sediment depths, hypoxic burial conditions, and low current regimes have good preservation potential.

These conditions characterize much of the western and the west-central areas of the northern Gulf. It cannot be stated unequivocally that vessels sinking in sediment-starved areas of the shelf, such as that of the eastern Gulf area, cannot be preserved, but based on results of this inquiry the probability seems low. In an area where burial or protection by fouling organisms exist, biofouling must be rapid in order to preserve vessel fabric or cargo. **Due to the small amount of data for the eastern** Gulf area, we cannot draw such conclusions. Until such data is available our expectation is that much of the eastern Gulf area will be characterized by poor preservation of historic shipwrecks.

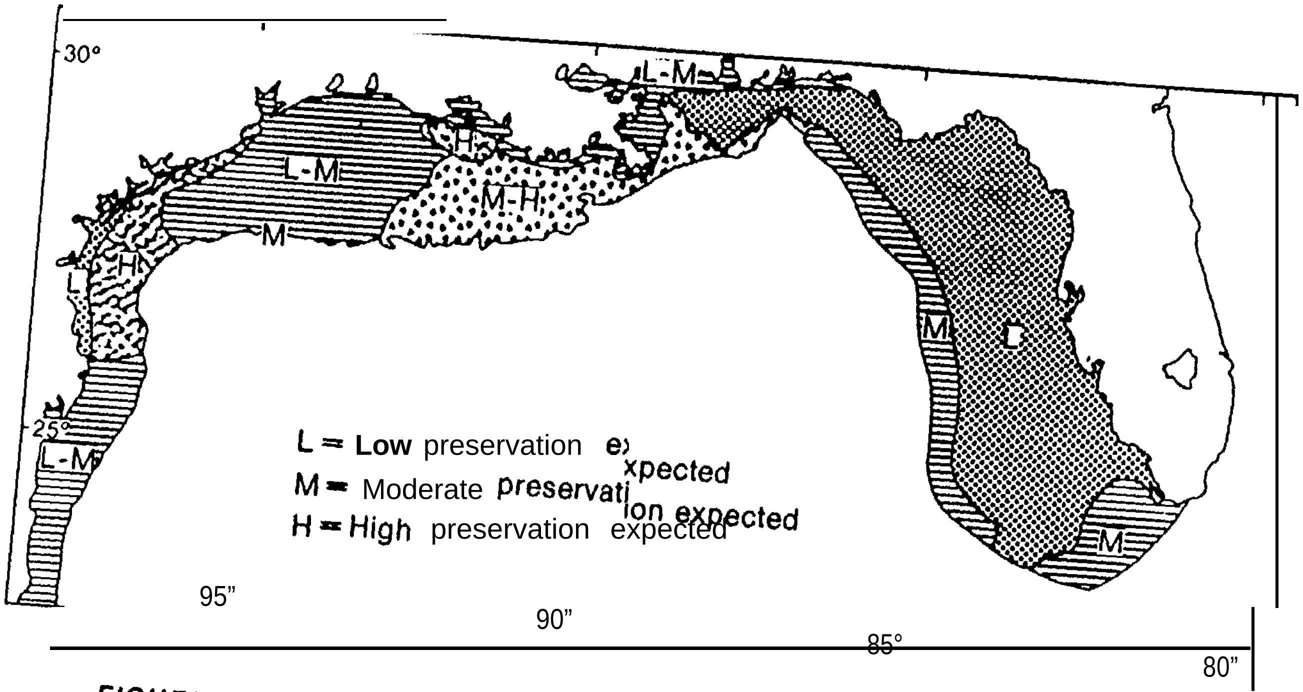


FIGURE II-50. Expected preservation potential and sediment distribution, northern Gulf of Mexico.

Exceptions are the cases of vessels sinking near to shore in the lee of headlands where sediment transport and current eddies provide a sand blanket to retard deterioration of ship remains.

10.4 A Reevaluation of Cultural Resource Management Zone 1

Cultural Resource Management Zone 1 (CRMZ1) as originally drawn (Plate 11, CEI 1975; Figure l-l) was assumed to contain 80 percent or more of the northern Gulf of Mexico shipwrecks. This assumption of shipwreck probability is conservative in comparison to other writers such as Marx (1971a) who cite values as high as 98 percent. As Muckelroy citing Bascom points out, the data supports the lower figure (Muckelroy 1978). The authors estimated that two-thirds of the total number of shipwrecks in the northern Gulf are within 1.5 km of the coast while the remainder lie between 1.5 and 10 km (CEI 1977). They conclude that wrecks are associated with the approaches to seaports, straits, shoals, reefs, and along the maritime routes. As we have seen in this study, the foregoing assumptions are largely supported by the data, but the authors deviate from their assumptions in the actual drawing of CRMZ1.

Generally, the CRMZ1 is far beyond 10 km off the coast. There are no reasons given for this. When we examine the total distribution of known shipwrecks developed by our study, the CRMZ1 boundary encompasses much of this overall density particularly west of the Mississippi delta. The eastern area of the northern Gulf departs sharply from this coincidence as deeper shipwrecks occur there. The results of multivariate analyses indicate a strong partitioning of shipwrecks chronologically which allows us to relate shipwreck patterns to historic changes in the northern Gulf of Mexico. Further, the AMC studies, a rough form of trend surface analysis, clearly illustrate that the pattern of shipwrecks coincide with factors such as port development, routes and hazards even when chronological considerations are waived. Four major groups, by chronological periods, were isolated by cluster analysis (Figure II-42) and nine groups by areas (Figure 11-44)s Using these results we can more confidently evaluate shipwreck potential across the northern Gulf of “Mexico.

Tables II-21 and II-22 summarize our expectations **for the potential of shipwrecks across the northern Gulf. We merged the observed frequency for shipwrecks in specific areas** with our assumptions concerning preservation in those areas to derive a rank-order scale of this potential. Again, this classification is more of an extended hypothesis than a comprehensive recapitulation of the actual situation for the vast sweep and variability of the OCS.

Where we have assigned “low” values to an area or subarea we are simply stating that the preservation and/or density of shipwrecks is generally lower than that expected for other areas. Drawing on our statistical analyses (Figure II-44) we define our shipwreck density values as follows: low ≤ 1 75 shipwrecks per area; moderate = **175-500** shipwrecks per area; high ≥ 500 shipwrecks per area. Exceptions such as the New Ground Reef wreck and the SAN JOSE both **lie** in low preservation potential areas based on the general picture seen for shipwrecks in the Keys-Tortugas area. Here the redeposition of the coarse-grained sediments preserved significant portions of these historic wrecks. Further out on the Florida platform we do not expect to see this movement of sediments and we expect low preservation in this area.

The conclusions we offer are derived from our present understanding of the shipwreck archaeology in the northern Gulf of Mexico. Our study results indicate:

1. Increased distribution of shipwrecks in the eastern Gulf area beyond the present CRMZ1 boundary but a lower preservation potential relative to the central and western Gulf;

2. Previous underestimations of early shipwrecks in the central and eastern Gulf areas; and

3. Increased potential of unreported shipwrecks in high density areas, e.g. a higher probability of finding wrecks in these zones because of higher preservation potential.

Recommendations for revisions of the CRMZ1 include:

1. Move the current CRMZ1 to within 10 km of the Gulf coast based upon the distribution of reported shipwreck locations and their probability of preservation.

2. Delineation of specific higher probability zones to reflect the increased frequency of shipwrecks in the vicinity of ports and certain hazards. They should have guidelines at least equal to those for the CRMZ1 and include:

   a. Brazes Santiago-South Padre Island (TEXAS);
   b. Corpus Christi-Mustang Island (TEXAS);
   c. Freeport-Matagorda Island (TEXAS);
   d. Galveston-High Island (TEXAS);
   e. Sabine River (TEXAS);
   f. Calcasieu (LOUISIANA);
   g. Barataria Bay/Grand Isle (LOUISIANA);
   h. West Bay-Mississippi Delta (LOUISIANA);
   i. East Bay-Chandeleur Islands (LOUISIANA);
   j. Mississippi-Alabama Barrier Complex (Cat, Ship, Horn, Petit Bois, Dauphin Island) (MISSISSIPPI-ALABAMA);
   k. Pensacola-Santa Rosa Island (FLORIDA);
   1. Apalachicola-Cape San Bias (FLORIDA);
   m. Cedar Key (FLORIDA);
   n. Tampa-St. Petersburg (FLORIDA);
   o. Cape Sable (FLORIDA) ; and
   p. Dry Tortugas-Marquesas (FLORIDA).

3. **Recognize individual blocks outside high probability zones and CRMZ1 proper according to the occurrence** of specific historic shipwrecks. These blocks and immediately adjacent blocks should be considered as localized high probability areas such that surveys should consider the specific block and the eight contiguous blocks.

Surveys conducted within these newly defined zones should utilize the survey methods recommended based on the results of the second part of this study.

Table 11-21.

PRESERVED SHIPWRECK PROBABILITY FOR GENERAL AREAS.

Areas	Shipwreck Potential	Preservation otential	Overall otentia
RIO	LOW	HIGH	MODERATE
WES	HIGH	HIGH	HIGH
CEN	HIGH	MOD-HIGH	HIGH-MOD
CENLA	HIGH	HIGH	HIGH
MSAL	MOD	MOD	MOD
WFL	MOD	MOD	MOD
BB	MOD	LOW	LOW-MOD
MG	MOD	LOW	LOW
SWFL	LOW	LOW	LOW
KEYTO	HIGH	LOW	MOD

Table II-22.

PRESERVED SHIPWRECK PROBABILITY FOR GENERAL AREAS & **SUB-AREAS**[7]

Areas & _ub-areas	Shipwreck Petential	Preservation Potential	Overall _otential
RIO	LOW	HIGH	**MODERATE**
South Padre	HIGH	HIGH	HIGH
South Padre East	LOW	HIGH	MOD
WESTERN(WES)			
South Padre	HIGH	HIGH-MOD	HIGH
North Padre	MOD	MOD-HIGH	MOD
Mustang Is.	HIGH	MOD-HIGH	HIGH
Matagorda Is.	MOD	MOD-HIGH	MOD
S.P. East	LOW	HIGH	MOD
N.P. East	LOW	HIGH	MOD
M. Is. East	LOW	HIGH	MOD
Mat. 1. East	LOW	HIGH	MOD
CENTRAL (CEN)	HIGH	MOD-HIGH	MOD-HIGH
Matagorda Is.	HIGH	HIGH	HIGH
Brazes	HIGH	HIGH	HIGH
Galveston	HIGH	MOD-HIGH	HIGH
High Is.	HIGH	MOD	MOD-HIGH
Sabine Pass	HIGH	MOD-HIGH	HIGH
West Cameron	LOW	MOD-HIGH	MOD
Brazes So.	LOW	MOD-HIGH	MOD
Gal. So.	LOW	HIGH	MOD
H. Is. So.	LOW	HIGH	MOD
H. Is. East	LOW	MOD	LOW-MOD
H. Is. East So.	LOW	MOD	LOW-MOD
W.C. West	LOW	MOD-HIGH	MOD
W.C. South	LOW	MOD-HIGH	MOD
CENLA	HIGH	MOD	MOD
East Cameron	MOD-HIGH	HIGH	MOD
Vermilion	MOD-HIGH	HIGH	MOD
South Marsh Is. N.	MOD-HIGH	HIGH	MOD
Eugene Is.	MOD	HIGH	MOD
Ship Shoal	MOD	HIGH	MOD
South Pelto	MOD-HIGH	HIGH	MOD
Grand Isle	HIGH	HIGH	HIGH
West Delta	HIGH	HIGH	HIGH
South Pass	HIGH	HIGH	HIGH
E.C. So.	MOD	HIGH	MOD
S.M. IS.	MOD	HIGH	MOD
S.M. Is. So.	LOW-MOD	HIGH	MOD
E. Is. So.	LOW-MOD	HIGH	MOD
S.S. SO.	LOW-MOD	HIGH	MOD

Table II-22
(continued).

South Timbalier	MOD	HIGH	MOD
S.T. S.	MOD	HIGH	MOD
Ewing Bank	LOW	HIGH	MOD
G. Is. So.	LOW-MOD	HIGH	MOD
W.D. So.	MOD	MOD	MOD
S.P. so.	MOD	LOW	LOW-MOD
MSAL	MOD	MOD	MOD
Breton Sound	HIGH	MOD	MOD
Main Pass	HIGH	MOD	MOD-HIGH
Chandelier	HIGH	MOD-HIGH	MOD-HIGH
Mobile	HIGH	MOD	MOD-HIGH
S.P. East	MOD	LOW-MOD	LOW-MOD
Ch. East	MOD	HIGH	MOD-HIGH
M.P. So. & East	LOW	LOW-MOD	LOW
Viosca Knoll	LOW	MOD-HIGH	LOW
Mobile So.	LOW	HIGH	MOD
WFL	MOD	MOD	MOD
Pensacola	MOD	MOD	MOD
Pen. So. 1	Low	HIGH	MOD
Pen. So. 2	LOW	HIGH	MOD
BB	MOD	LOW	LOW-MOD
Apalachicola	MOD	LOW	LOW
Ap. so.	LOW	LOW-MOD	LOW
MG	MOD	LOW	LOW
Gainesville	LOW	LOW	LOW
Tarpon Sp.	MOD	LOW	LOW
SW FL	LOW	LOW	LOW
Tampa	LOW	Low	LOW
T.W.	LOW	LOW	LOW
St. Petersburg	LOW	LOW	LOW
Charlotte Harbor	LOW	LOW	LOW
KEYTO	HIGH	LOW	MOD
Pulley Ridge	LOW	LOW	LOW
Miami	LOW-MOD	LOW	LOW
Dry Tortugas	HIGH	MOD	MOD

‘Sub-areas identified by use of MMS lease area additions e.g. West Cameron; Appalachicola South, etc. (cf. MMS Visual No, 4, 1986)

Task II Establishing an Interpretive Framework to Characterize Unidentified Magnetic Anomalies and Side-Scan Sonar Contacts

11.0 INTRODUCTION

The Minerals Management Service (MMS) established the boundaries of Cultural Resource Management Zones 1 and 2 based on the results of the 1977 baseline study, *Cultural Resource Evaluation of the Northern Gulf of Mexico Continental Shelf.* Cultural Resource Management Zone 1 (CRMZ1 or Zone 1) was defined based on the higher probability of historic shipwreck sites. Zone 2's definition was based primarily on the occurrence of prehistoric cultural resources.

All the blocks within Cultural Resource Management Zone 1 (Figure II-51), also lie within the area of high industry interest including 69 of the 90 tracts (77 percent) in the central Gulf planning area (Figure II-52) (Brashier, Beckert and Rouse 1983).

About 39 percent (1 ,770) of the 4,592 blocks within the central area are in Zone 1. MMS estimates that of the 278 blocks leased in the central Gulf, approximately 108 blocks (39 percent) occur within Zone 1.

The two principal instruments for shipwreck detection are the magnetometer and the side-scan sonar. At 150 m linespacing the magnetometer gives about 25-30 percent coverage of the sea floor, which constitutes only a sampling survey (Clausen and Arnold 1975). However, at this linespacing, side-scan sonar can cover over 100 percent of the sea floor with good resolution.

Conducting surveys at 150 m linespacing is based on the premise that detection of all unidentified magnetic anomalies and side-scan contacts recorded within a survey area will result in the avoidance, and therefore, the protection of historically significant shipwrecks. This assumes that either all parts of a shipwreck are ferromagnetic and would be recorded by the magnetometer, or that all nonferromagnetic parts of a wreck would be evident on the side-scan records. Neither is necessarily the case.

In areas with a relatively hard bottom or in areas with only a thin sediment layer, it is probable that there would be some evidence on the side-scan sonar records of any shipwreck within a survey area. However, over large portions of the OCS, particularly the central and western planning areas, the thickness of unconsolidated sediments is sufficient to conceal debris from most pre-20th century wrecks of wooden or composite construction (Clausen and Arnold 1975). According to the results of studies conducted by various marine archaeologists in their work with shipwrecks (Clausen and Arnold 1975; Watts 1980; Arnold 1982a, and Saltus 1982) at 150 m linespacing, it is possible to pass by an historically significant shipwreck with no indication on the magnetometer record.

In practice, archaeologists preparing cultural resource reports for lease block surveys consider anomalies over five nanoteslas (nT) with a period of three or more counts as a possible target. From a magnetic contour map of a 16th century Spanish shipwreck site (Figure II-53) present methodology cannot detect anomalies on more than two lines (Arnold and Clausen 1975). To illustrate this point, a 150 m grid was superimposed on the magnetic contour of the Spanish wreck as shown. The "A" pattern detects the site on only two lines with three separate anomalies that have magnetic amplitude no greater than five nanoteslas. Moving the entire survey grid to the right 50 m produces the "B" pattern, which detects three anomalies with a magnetic amplitude of 40 nT and two of five nT intensity, and is only observed on one line. The "C" pattern is achieved by moving the grid 50 m farther to the right and shows one anomaly at 30 nT amplitude with two peaks. The "D" pattern, which occurs when the grid is shifted approximately 45 degrees, detects no anomalies.

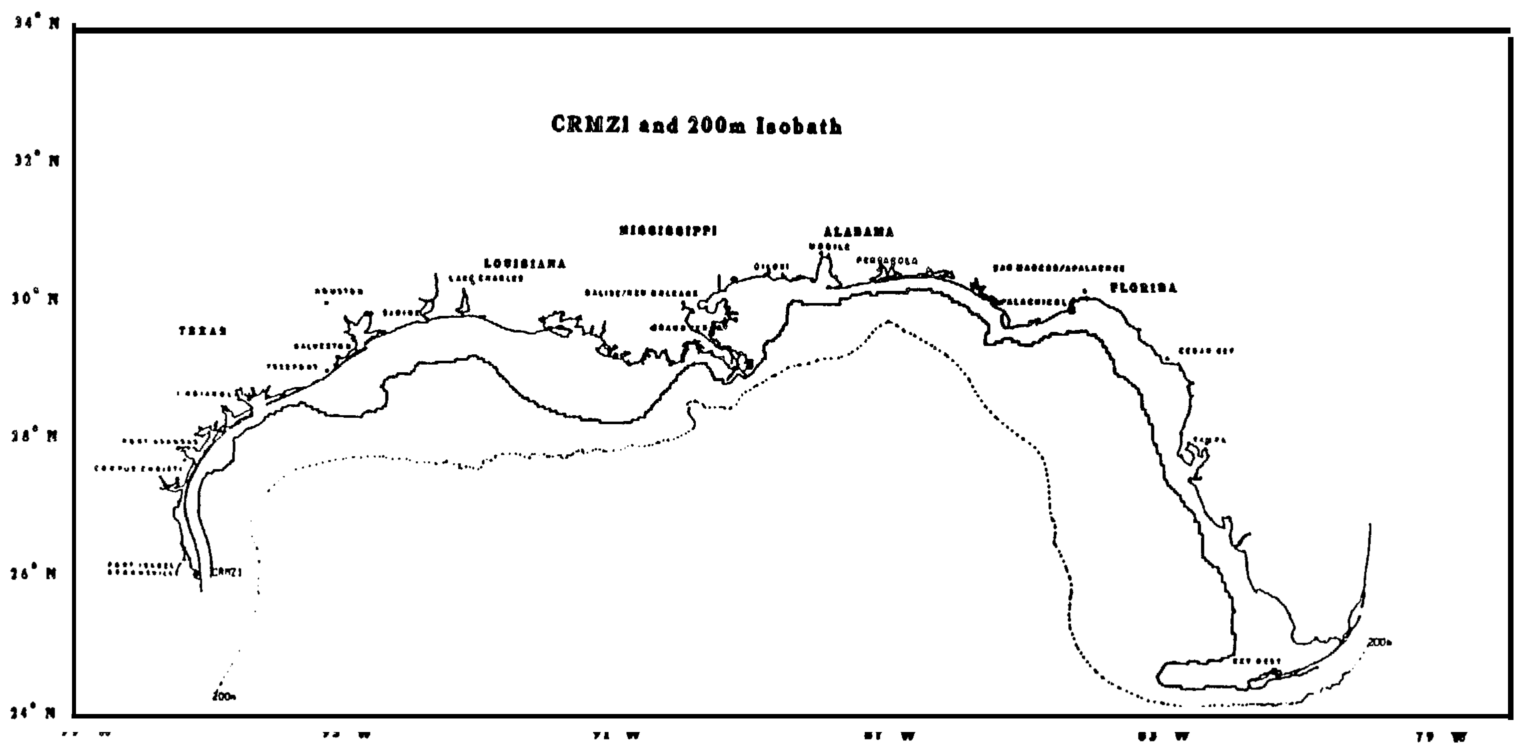


FIGURE -51. Cultural Resource Management Zone 1 and the Outer Continental Shelf, Gulf of Mexico.

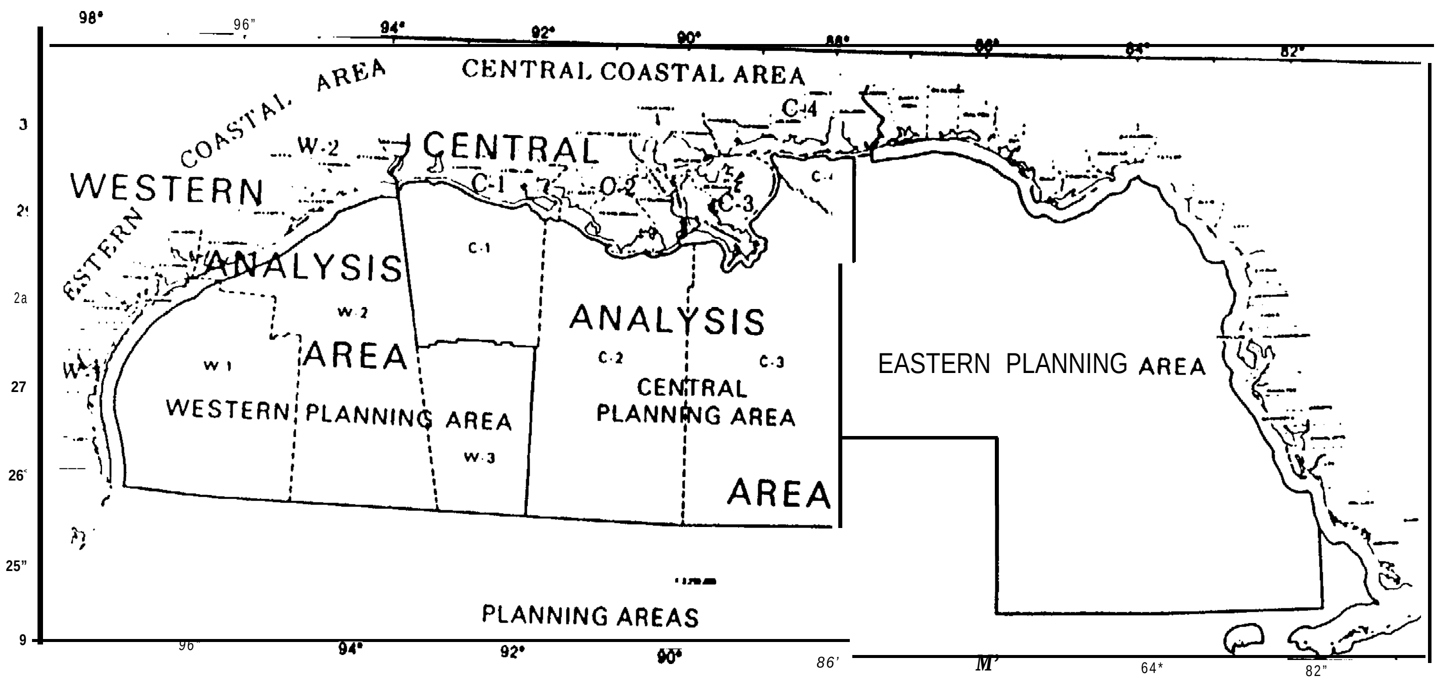


FIGURE II-52. Northern Gulf planning areas.

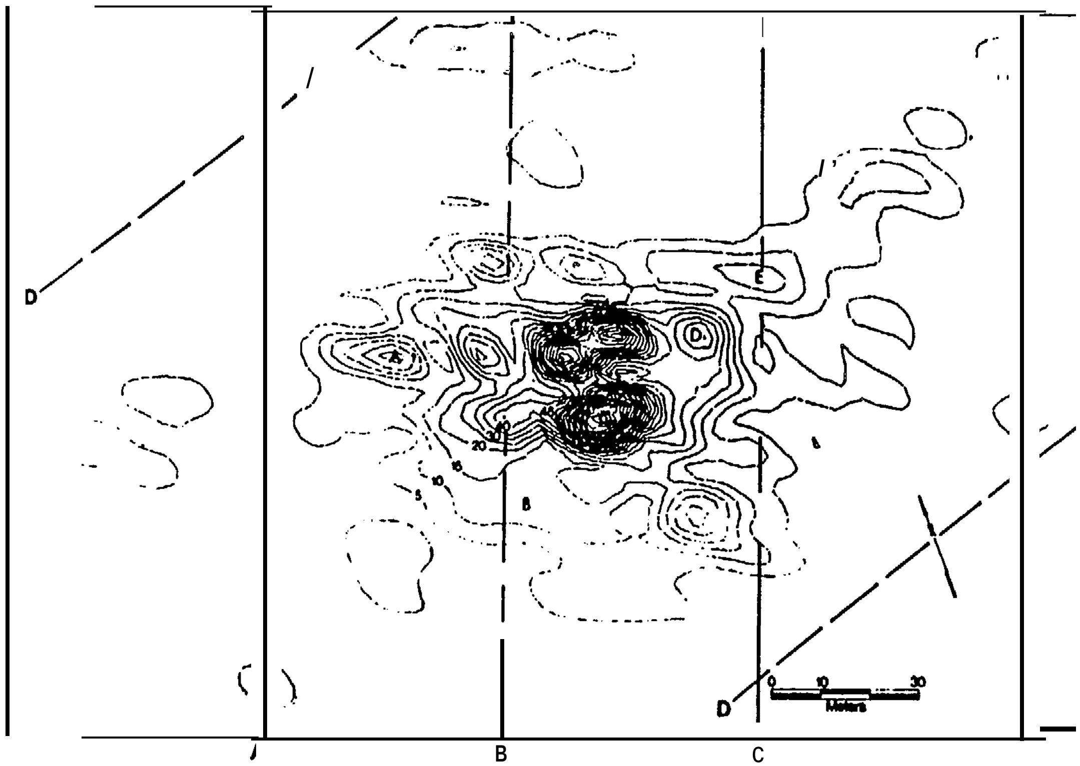


FIGURE II-53. Magnetic plot of 16th century shipwreck.

Adding to the linespacing problem are single objects lost or disposed of, such as shrimp net boards, lengths of chain, cable, pipe, steel drums, ordnance and seismic gear, which yield low amplitude anomalies. It has been observed that small, near surface faulting also produces a 5-6 nT anomaly for a period of five to seven counts. A geological phenomenon is usually observed as a small anomaly of two to five nT recorded over a long duration whereas cultural material are characterized by larger amplitude anomalies and shorter duration (CEI 1977).

After 1977, concerns about the detection and characterization of anomalies in cultural resources surveys continued to surface in the literature. Arnold (1980) compared the results of underwater remote sensing surveys done for research purposes with the results of those done for cultural resources management. He concluded that the empirical data emphasizes the inadequacy of the 150 m linespacing for the detection, much less the characterization, of anomalies. Arnold (1982) makes a strong case for the use of groundtruthing to identify and characterize anomalies.

In 1986, MMS continued the dialogue on this issue and hosted a session at the Seventh Annual Information Transfer Meeting (ITM) entitled, “Marine Archaeology: A Problematic Approach to Resolution of Unidentified magnetic Anomalies” (MMS 1986). Arnold reiterated his criticism of survey methodology based on the 150 m linespacing saying pattern recognition and anomaly characterization based on such patterning could not be reliably done using this methodology. Garrison presented his results of a study of the 19th century shipwreck (WILL O’ THE WISP) using 25 m linespacing. He concluded that of three factors commonly used to characterize underwater magnetic anomalies--amplitude (intensity), signature (shape), and duration (period) --only duration was significant at over 100 m distant from an anomaly. Saltus contended that only groundtruthing could determine the cause and significance of magnetic features. Bevan suggested new instrumental approaches to the problem of anomaly characterization while Weymouth counseled the translation of the factor of time (in seconds) to distance so it could more readily be used in equations and nomograms for the estimation of the size and nature of the magnetic source. Following this tack of the simple application first principles, he urged the use of the full width, half maximum (FWHM) number for estimation of depth or distance of anomalies (MMS 1986).

The question of how best to identify anomalies centers on issues of methodology. The characterization of anomalies is inhibited by the lack of data. Current cultural resource remote sensing surveys cannot provide a level of data adequate to reasonably evaluate anomalies. Groundtruthing of anomalies is viewed as a logical and common step in most remote sensing. It has been wholly lacking in cultural resource remote sensing surveys carried out on the Gulf of Mexico OCS due to a policy of avoidance adopted by industry.

11.1 Objectives

As a result of MMS required lease block remote sensing surveys, numerous unidentified magnetic anomalies and side-scan sonar contacts which could represent historic shipwrecks have been recorded in the Gulf of Mexico OCS. These Gulf of Mexico surveys have also recorded numerous examples of relict late Wisconsin landforms (fluvial channels with evidence of terraces and point bars, bays, lagoons, barrier islands, natural levee ridges, salt diapirs, and sinkholes) which have a high probability for associated prehistoric sites to occur.

Avoidance or further investigation of archaeologically sensitive areas is usually required prior to approval of lease permits; however, because industry has generally chosen avoidance rather than further investigation of these areas, little to no data have been collected which would help in building an interpretive framework for the evaluation of unidentified magnetic anomalies and side-scan sonar contacts, or in evaluating the predictive model for prehistoric site occurrence.

Based on Task 1, we have indicated areas on the GOM OCS that have high, moderate, and low probabilities for the occurrence of historic shipwrecks. Task II of this study was designed to establish an interpretive framework to characterize unidentified magnetic anomalies and side-scan sonar contacts within the CRMZ1. It has the following two efforts: (1) Information collection; and 2) information analysis and synthesis. Two previously surveyed lease blocks (one that was not subsequently developed, and one that has been developed) were resurveyed for magnetometer and side-scan sonar data with survey linespacing at 50 m, and navigation system accuracy at ±5 m. These data and the data from the original lease block survey were analyzed to determine the following:

1. The percentage of anomalies recorded during the survey at 50 and 100 m linespacings that was recorded during the original lease block survey at a 150 m linespacing;
2. The correlation in anomaly locations, amplitude, duration, and signature (dipolar/monopolar) between the original and new surveys; and
3. The number of new magnetic anomalies and/or side-scan contacts that were recorded within the developed lease block, and the location of these anomalies relative to oil and gas structures.

Sites within lease blocks were selected for groundtruthing and signature characterization of unidentified magnetic anomalies without associated side-scan sonar contacts, unidentified side-scan sonar contacts without associated magnetic anomalies, and unidentified magnetic anomalies with associated side-scan sonar contacts. Anomalies were chosen from the resurvey sites as discussed above.

Groundtruthing and signature characterization included the following:

1. Relocating the anomaly or contact and collecting magnetometer and/or side-scan sonar data at a linespacing of 50 m or less.
2. Constructing a three-dimensional magnetic contour map of the unidentified magnetic anomalies, and magnetic anomalies with associated side-scan sonar contacts.
3. Identifying the source of the anomalous contact through diver inspection, using a hand held magnetometer.
4. Photographing any marine debris and historic shipwrecks where observable at the seafloor.

The results of the resurvey and groundtruth efforts include:

1. Post-plot maps that show the track of the survey vessel and navigational fix points at a 1:1200 scale and compare the findings of the original lease block survey with the resurvey data.
2. Contour maps with a two gamma contour spacing of each magnetic anomaly that was investigated, and a catalogue of magnetic signatures for each object.
   (a) The survey and groundtruthing methods, and the instrumentation used is described and survey and diving findings are discussed.
   (b) All the data collected during the field surveys were analyzed to determine the relationship between survey linespacing and anomaly detection, the influence of oil and gas structures on magnetic anomaly distribution and to characterize the changes at different distances and orientations to the magnetic sensors. The goal of the pattern recognition analysis of magnetic and side-scan sonar signatures is to develop a method that differentiates resources, and that can be used by MMS cultural resource analysts in the cultural resource survey review process.

12.0 METHODS

12.1 Data Collection - Resurveys of Lease Blocks

12.1.1 Selection Criteria

A search of MMS files was conducted to determine candidate blocks for the Task II study. Criteria used in our selection included:

1. Block within Cultural Resource Management Zone 1;
2. High data quality;
3. Block development (yes or no);
4. Sensor tow depth known or could be determined; and
5. Freeport/Galveston area location.

The list of potential blocks were examined using these criteria are seen in Table 11-23. Item 5 was considered from a logistical standpoint because this location allowed access to large portions of the Texas aspect of CRMZ 1. Consideration was given to using study blocks off western Louisiana as the study team was equally familiar with these waters having carried out oceanographic studies in the Cameron area for over four years (Gittings, et. al. 1982; DeRouen, et.al. 1982, 1983; Harm, et. al.1984).

An additional factor in the selection of the area was the available information concerning known shipwrecks in those areas. The Texas data was more extensive than for any other state. Further, hydrocarbon exploration and development has been extensive on the OCS off Galveston. A final factor in the selection of blocks to be resurveyed was water depth. While it is possible to work near the edge of the OCS with SCUBA: (a) the CRMZ 1 typically does not extend this far; and (b) the more time the divers can reasonably spend at a depth without exceeding decompression limits provided a key safety factor for groundtruthing activities.

With these criteria in mind, three blocks were selected for resurvey from the Galveston Lease Area--GA 324, GA 313, and GA 332 (Figures II-54 and II-55).

12.1.2 Sampling Considerations

Obtaining a valid sample from 4000 potential lease blocks within CRMZ 1 exceeded the economic limits of this study. Recognizing this, we attempted to maximize our sampling of variability within a sample population of three blocks. We selected to resurvey two halves (GA 324 and GA 332) of the undeveloped block and one whole developed block. The use of a half block approach in GA 332 was to maximize comparability between the original survey and our resurvey of it.

12.1,3 *Analysis of Resurvey Data - Objectives*

These **resurvey** data and the data from the original lease block survey were analyzed to determine the following:

a. The percentage of anomalies recorded during the survey at 50 and 100 m linespacings that was recorded during the original lease block survey at a 150 m linespacing;
b. The correlation in anomaly locations, amplitude, duration, and signature between the original and new surveys; and
c. The number of new magnetic anomalies and/or side-scan contacts that were recorded within the developed lease block, and the location of these anomalies relative to oil and gas structures.

Table II-23.

LIST OF POTENTIAL LEASE BLOCKS FOR TASK II STUDY[3].

Developed Blocks & Lease	Undeveloped Blocks & Lease #
GAL 385 (#8132)	GAL 379 (#81 29)
GAL 210 (#7236)	GAL 380 (#8130)
BR 397 (#6060)	BR A-27 (#8121)
BR A-50 (#7229)	GAL 386 (#81 33)
GAL 361 (#61 11)	GAL 359 (#8551)
BR 494 (#6071)	GAL 346 (#7248)
GAL 345 (#61 07)	GAL 347 (#7249)
GAL 313 (#6098)	MAT 688 (#8548)
GAL 300 (#6097)	GAL 191 -F (#7235)
BR 550 (#6080)	BR 476 (#6066)
GAL 271 (#6096)	BR 491 (#6069)
BR 608 (#6083)	GAL 332 (#61 03)
GAL 211 (#6094)	GAL 344 (#61 06)
N PADRE 969 (#5953)	BR 512 (#6075)
N PADRE 976 (#5954)	BR 534 (#6077)
MAT 67'3 (#81 04)	BR 615 (#6084)
	BR A-67 (#7232)
	GAL 347 (#7249)
	GAL A-99 (#7258)
	MAT 680 (#8547)
	GAL 460 (#81 34)
	GAL A-74 (#81 37)
	GAL 324 (#81 27)

TOTAL=39

The following list of potential lease blocks were selected for further study from which to determine the sample to be surveyed with the 50-meter line spacing methodology:

Developed Blocks & Lease #	Undeveloped Blocks & Lease #
GAL 313 (#6098)	GAL 460 (#8134)
GAL 271 (#6096) (partial block)	GAL 191-F (#7235) (partial block)
GAL 210 (#7236)	GAL 359 (#8551) (partial block)
GAL 385 (#81 32) (partial block)	GAL 386 (#81 33)
GAL 211 (# 6094) (partial block)	GAL 346 (#7248) (partial block)
	GAL 347 (#7249) (partial block)
	GAL 324 (#81 27)
	GAL 332 (#6103) (partial block)

TOTAL =13

[3]Source: MMS Lease Edit/Update Program

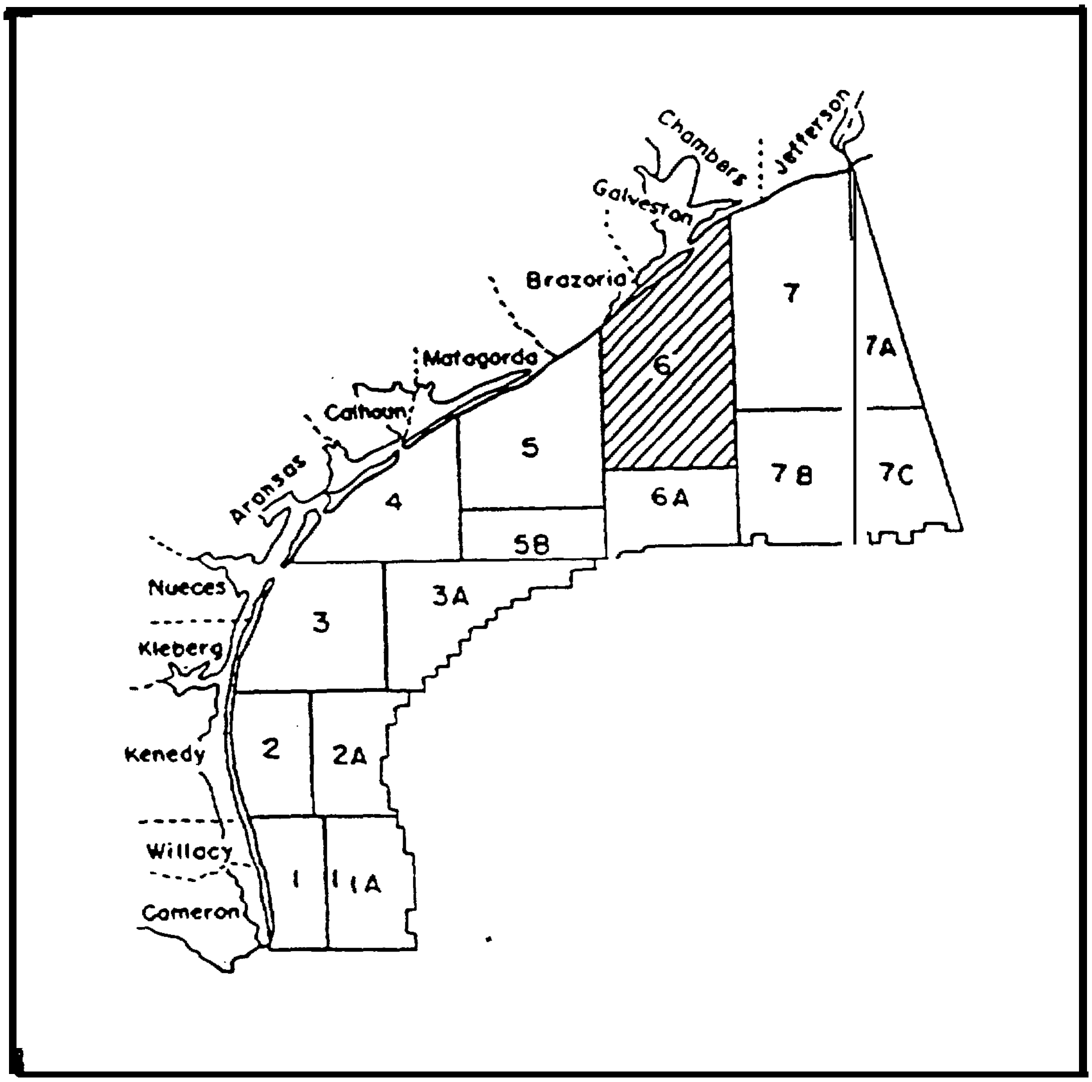


FIGURE II-54. **Galveston lease area.**

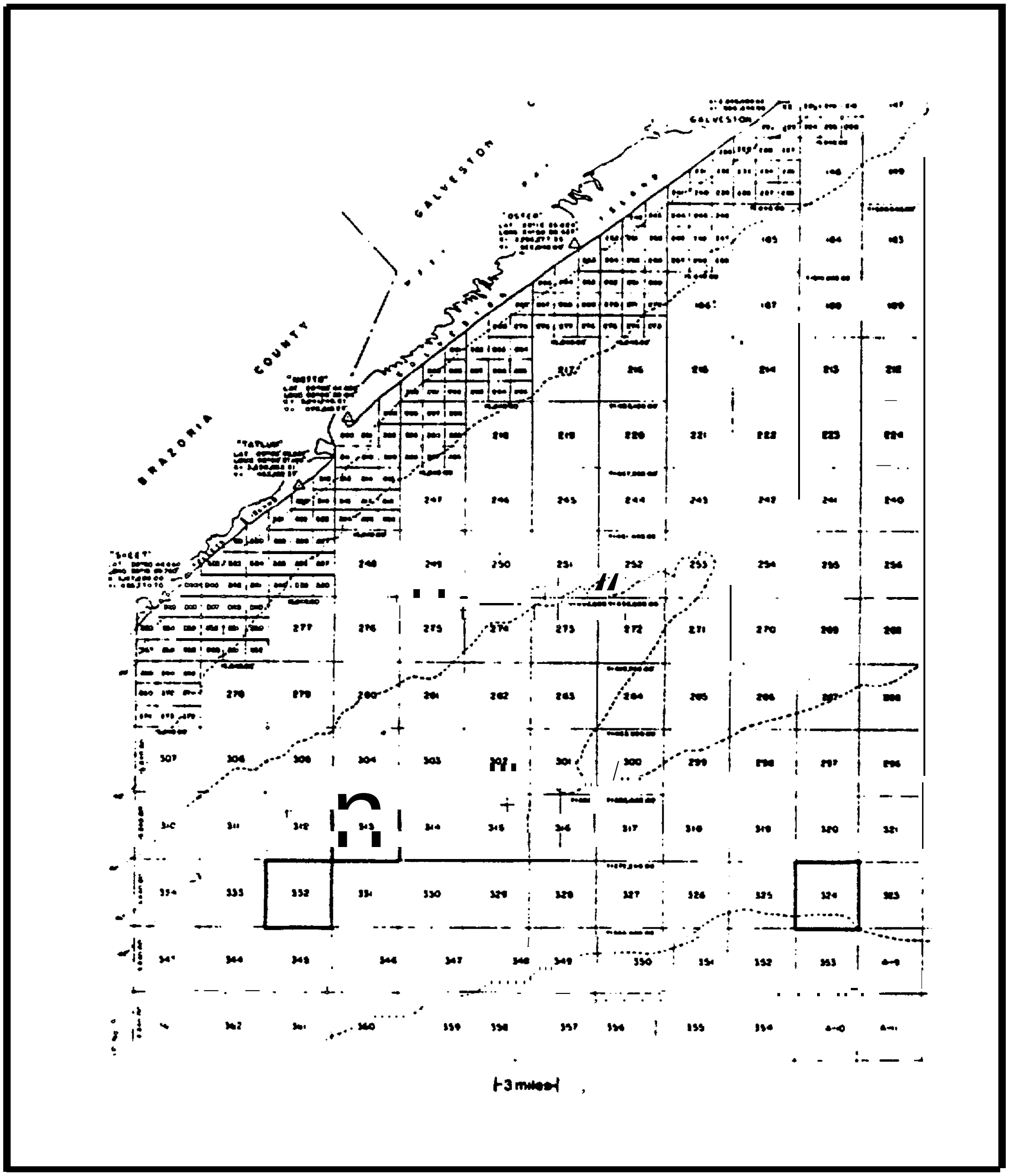


FIGURE II-55. Study blocks - Galveston area.

These analytical steps were defined by MMS in order to determine the relationship between linespacing of a magnetometer and side-scan sonar and the detection of objects at or below the sea floor. Further, the magnetometer data were subjected to various digital filtering, spectral analysis techniques, and algorithms useful in digital signal processing. The intent of this processing was to examine more clearly magnetometer parameters such as amplitude, duration and signature shape.

12.2 Data Collection - Groundtruthing Studies

12.2.1 *Sample Size Consideration in Groundtruthing Studies*

A sufficiently large population of anomalies was selected so that pattern recognition and associated statistical analyses could be performed. A sample size from the three classes: (1) unidentified magnetic anomalies without side-scan sonar contacts; (2) unidentified side-scan sonar contacts without associated magnetic anomalies; and (3) unidentified magnetic anomalies with side-scan sonar contacts was selected using standard statistical methods. Each class was split into cultural resource or recent debris (i.e., p or q). It is difficult to justify an exact number for the sample size in this study. Laserwitz (1968), uses the fact that the numerator in the formula for the variance of a sample proportion reaches its maximum value when the proportion is 0,5, when **p** and q are not known. A conservative estimate for sample size is simply

$$n = 1/k^2$$

Where k is the desired interval about 0.5 at the 95 percent confidence level.

This interval is an estimate of precision such that the confidence limits vary by a fixed percent about the value 0.5. Taylor (1961) set confidence limits and precision to estimate the sample size by similar methods (Craddock 1969).

Using Lazerwitz's method and requiring a precision of 0.1 (i.e. **a limit of ±20** percent about p), our n = 100; using a value of 0.2 we obtained a sample size of 25. In terms of confidence limits, assuming a normally distributed population, such a small sample is less reliable than a value calculated from a larger sample. Because the sample size is small the use of the t-distribution is necessary to set confidence limits. Here the degrees of freedom, n-1, are such that the sample mean may differ more than 2 degrees from that of the population selected. Still the value of our mean will be a standard deviation approaching ± 40 percent. This number then is primarily justified in terms of utilizing available study time and funds. In the actual study, 27 sites were examined during groundtruthing cruises.

12.2.2 *Groundtruthing Procedures - Characterization Objectives*

Groundtruthing and signature characterization included the following:

1. Relocating the anomaly or contact and collecting magnetometer and/or side-scan sonar data at a linespacing of 50 m or less;
2. Constructing a SYNVIEW magnetic contour map and magnetic profile map of the unidentified magnetic anomalies, and magnetic anomalies with associated side-scan sonar contacts;

3. Identifying the source of the anomalous contact through diver inspection, using hand held magnetometer and/or metal detectors and sediment probing devices as necessary; and
4. Photographing any marine debris and historic shipwrecks where observable at the sea floor.

The objective of this procedure was to compile a sample inventory that would reflect a real population of shipwrecks or modern debris in the survey areas and, to a large degree, the Gulf of Mexico.

13.0 FIELD STUDIES

13.1 **Resurvey -** Lease Blocks

13.1.1 GA 324- Location and Description

Galveston area lease block 324 is 46 km east-southeast of Surfside, Texas (Figures 11-54 and II-55), in water depths of 22 to 25 m. The sea floor slopes evenly southward at a mean gradient of 1:2,000 (0.03) in the northwest quadrant changing to a southwest-southward slope around the toe of Heald Bank with a gradient of 1:3,000 (0.02) (Figure 11-56). The sea floor is smooth and featureless with some small scale local relief in the southwest corner. Bottom sediments consist of Colorado and Brazes River lower delta slope and prodelta mud transitional eastward to sandier Heald Bank deposits (Curray 1960; CEI 1977). The original geophysical and archaeological assessment was done in 1985 by Gardline Surveys, Inc. for Kerr-McGee Corporation.

13.1.2 GA 313- Location and Description

Galveston area lease block 313 is 22.5 km south-southeast of Surfside, Texas, in water depths of 20 to 21 m. The sea floor slopes in the southwest corner at a gradient of 1:3,000 (Figures II-55 and II-56). The sea floor is smooth and featureless with no relief. The bottom sediments are silty sand overlying clay deposits. The Pleistocene horizon (Beaumont Clay Formation) is believed to be between 21 to 24 m below the present sea floor (McClelland Engineers 1979). The original geophysical and archaeological assessment work was done in 1984 by John E. Chance and Associates, Inc. for Superior Oil Company.

13.1.3 *GA* 332- *Location and Description*

Galveston area lease block 332 is 24 km south of Surfside, Texas (Figures II-55 and 11-56), in water depths of 20 to 27 m. The sea floor is smooth and featureless. The sea floor slope is less than 1:3,000. Bottom sediments are unconsolidated sandy silts. These overlie deeper (21 m) Pleistocene clays (McClelland Engineers 1979). The original geophysical and archaeological assessment was done in 1983 by John E. Chance and Associates, Inc. for Shell Offshore, Inc.

13.1.4 Instrumentation and Techniques of Resurvey

13.1.4.1 Magnetometer

The instrument used in the resurveys was a Geometries G-866 proton precision magnetometer. Three different cable lengths were utilized--76 m, 106 m, and 182 m as required by survey conditions. The G-866 has a BCD character serial output which was interfaced with a microcomputer for digital logging of all data. The resolution was typically 0.2 nT at 1.5 sec sample intervals.

This sample interval was necessitated by firmware parameters of the PROMS used by Geometries on this model. A factory modification allowed shorter intervals to be used but these were not utilized until groundtruthing surveys.

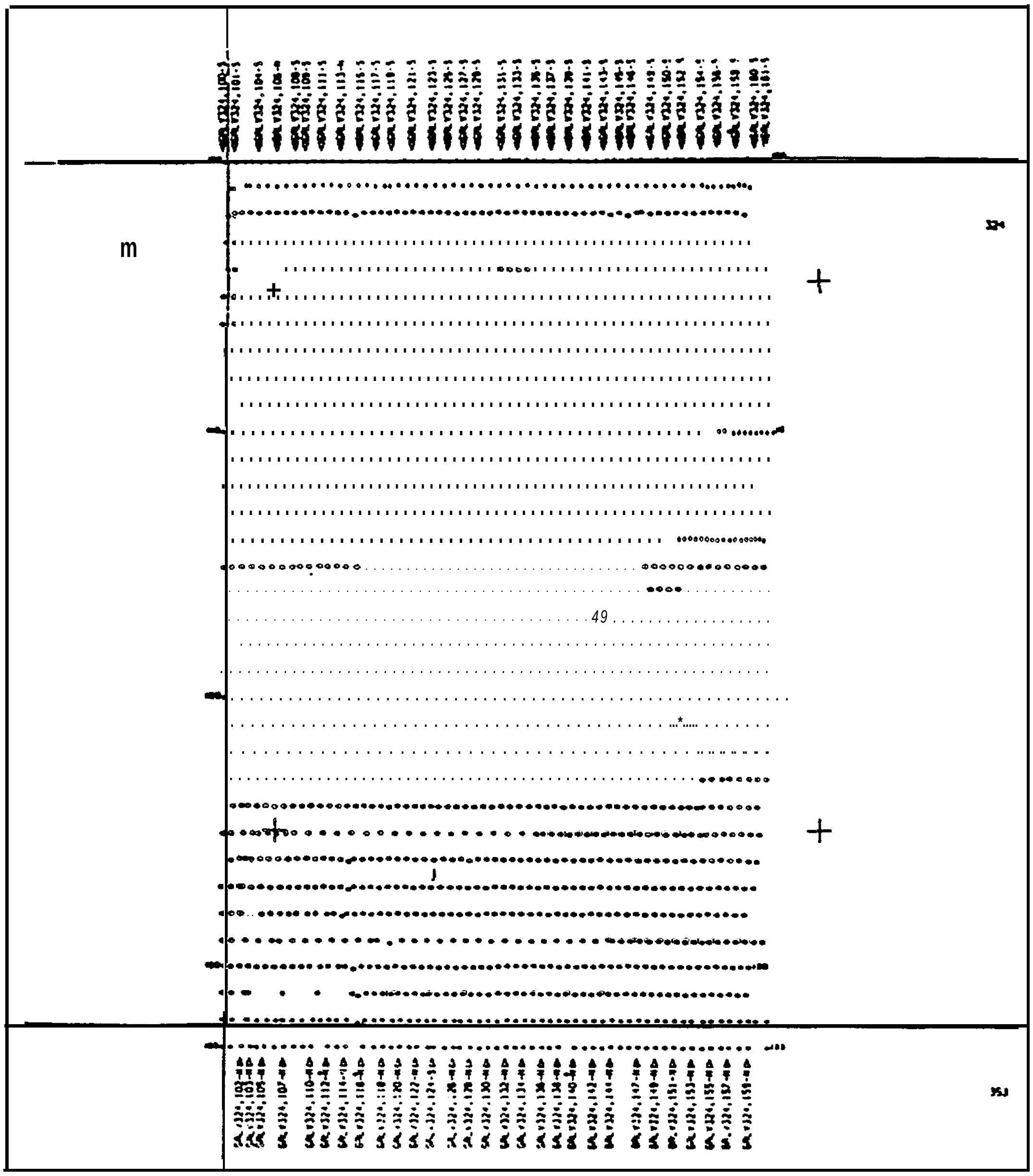


FIGURE II-56. Block GA 324 cruise tracks.

Typical Settings:
Sample Interval: 1.5 sec
Scale: 100/1,000 nT
Averaging: 0 to 3 point
Event Mark: 150 m

13.1.4.2 Side-scan Sonar

Two different instruments were used in separate resurveys. The EG&G Mark 1 B system consisting of a model 259-4 recorder and model 259, 100 kHz tow vehicle was used in the resurvey of Galveston Area block 324 (GA 324). For the resurvey of blocks GA 313 and GA 332, a digital model, the EG&G 260 side-scan sonar became available. This later instrument allowed faster more efficient survey due to its microprocessor controlled processing of that corrected for slant range and vessel speed. By comparison, to avoid excessive distortion in the noncorrected images taken with the Mark 1 B, we towed at 4-4.5 knots. The Model 260 could be towed at 8 knots but typically averaged 5 knots.

AH data were recorded on analog chart paper. Both instruments were interfaced to the navigation system for correlation of all timing fixes. Settings used were as follows:

EG&G Mark 1B
Range: 50 m
Frequency: 100 kHz
Event Mark: 20 sec

EG&G Model 260
Range: 75 m
Frequency: 100 or 500 kHz
Event Mark: 20 sec

13.1.4.3 Depth Sensor

The instrument used to constantly monitor the tow depth of the magnetometer sensor was a Teledyne Model 28951. The depth sensor was mounted on the cable ahead of the magnetometer sensor and the output depth read on a digital display. The update rate was 1.0 second and the accuracy was 0,3 m depth.

13.1.4.4 Depth Sounder

A Si-Tex depth recorder printer was operated with a 200 kHz hull mount transducer for maximum detail in the shallow water depths typical of the blocks chosen for resurvey. The instrument was adequate for high resolution bathymetry of the rather featureless sea floor in the three blocks. Combined with the side-scan sonar it enhanced our ability to relocate underwater contacts.

13.1.4.5 Navigation Systems - Medium and Short-range Systems

STARFIX - This satellite system was utilized in the resurvey of GA 324 due to the need for a precision navigation system with medium range (80 km) capability. This system operates in the microwave frequency band of four to six GHz (gigahertz). Accuracies are within 5 m of a position.

Navigation was accomplished by use of a Hewlett Packard Model 1000 minicomputer which converted range data from the STARFIX receiver into latitude and longitude coordinates. These in turn were used to steer preset course lines of desired lengths and offsets. Figure II-6 illustrates the precision in course lines using this system.

Del Norte Trisponder - This system is classified as short range (s80 km) and was used in the resurvey of GA 313 and GA 332. The system operates at 9.3 GHz and has an accuracy of 1-3 m of a position.

Navigation was accomplished using internal firmware steering and conversion programs of the Del Norte Model 542 distance measuring unit (DMU). The positional data was output from a serial port on the DMU to an interface with a Hewlett Packard Model 97 microcomputer using software which logged this data and simultaneous magnetometer readings to diskettes. Figure II-56 illustrates the course lines steered with this system.

13.1.5 Techniques of Resurvey

Utilizing the methodology required by the scope of services, the resurveys were conducted using 50 m offsets of survey lines in each of the three blocks chosen for restudy. Preplot navigation charts were prepared for each block as shown in the example for GA 313 and GA 332 (Figure II-57). These preplots were used in resurvey navigational programs.

In GA 324, 61 lines were resurveyed; GA 313, 102 lines were resurveyed; and GA 332 55 lines were resurveyed (Figures II-58 and II-59). This represents over half of GA 324, one-half of GA 332, and all of GA 313 for a total of two complete blocks resurveyed.

The control points established and used for the resurvey of GA 313 and GA 332 are shown in Table II-24. These were established by Dr. Robert Bruner of the survey division, Department of Civil Engineering, Texas A&M University. For GA 324 the resurvey utilized the STARFIX system so no controls were necessary other than those maintained by STARFIX to calibrate their satellite constellation.

As described in this section, all survey instrumentation and procedures comply with MMS Notice to Leasees 75-3 (NTL 75-3), Revision Number 1 with the exception that the survey linespacing was 50 m and navigation accuracy was 5 m of position. Typically, most surveys done under NTL 75-3 guidelines utilize such precision in navigation but do not exceed the 150 m in linespacing required by that directive. Specific techniques used in each block are described below.

13.1 .5.1 GA 324

a. Magnetometer - A weighted, 76 m tow cable and sensor array was deployed astern of the R/V EXCELLENCE II. This vessel is 20 m in length so the minimum distance for the sensor was never closer than 58 m to the vessel. This follows the general rule of thumb for towing distance of not less than twice the ship's length (Milne 1980).

b. Side-scan sonar - The 100 kHz EG&G Mark 1 B towfish was deployed just astern of the survey vessel (12 m). Range was set at 50 providing 25 overlap for adjacent survey lines.

13.1.5.2 GA 313 and GA 332

a. Magnetometer - A 106 m tow cable and sensor was deployed in the resurvey of these blocks. The length allowed the reduction of depresser weight on the cable used with the 72 m cable.

b. Side-scan sonar - The 100/500 kHz EG&G 260 side-scan sonar was used in the standard configuration astern the vessel during survey but used in what is termed a "bow deployment" during anomaly relocations. The dual frequency vehicle was towed directly under the vessel. This allowed the simultaneous correlation of sonar contact and geographic position as the tow fish was at the same point as the navigation system's antenna.

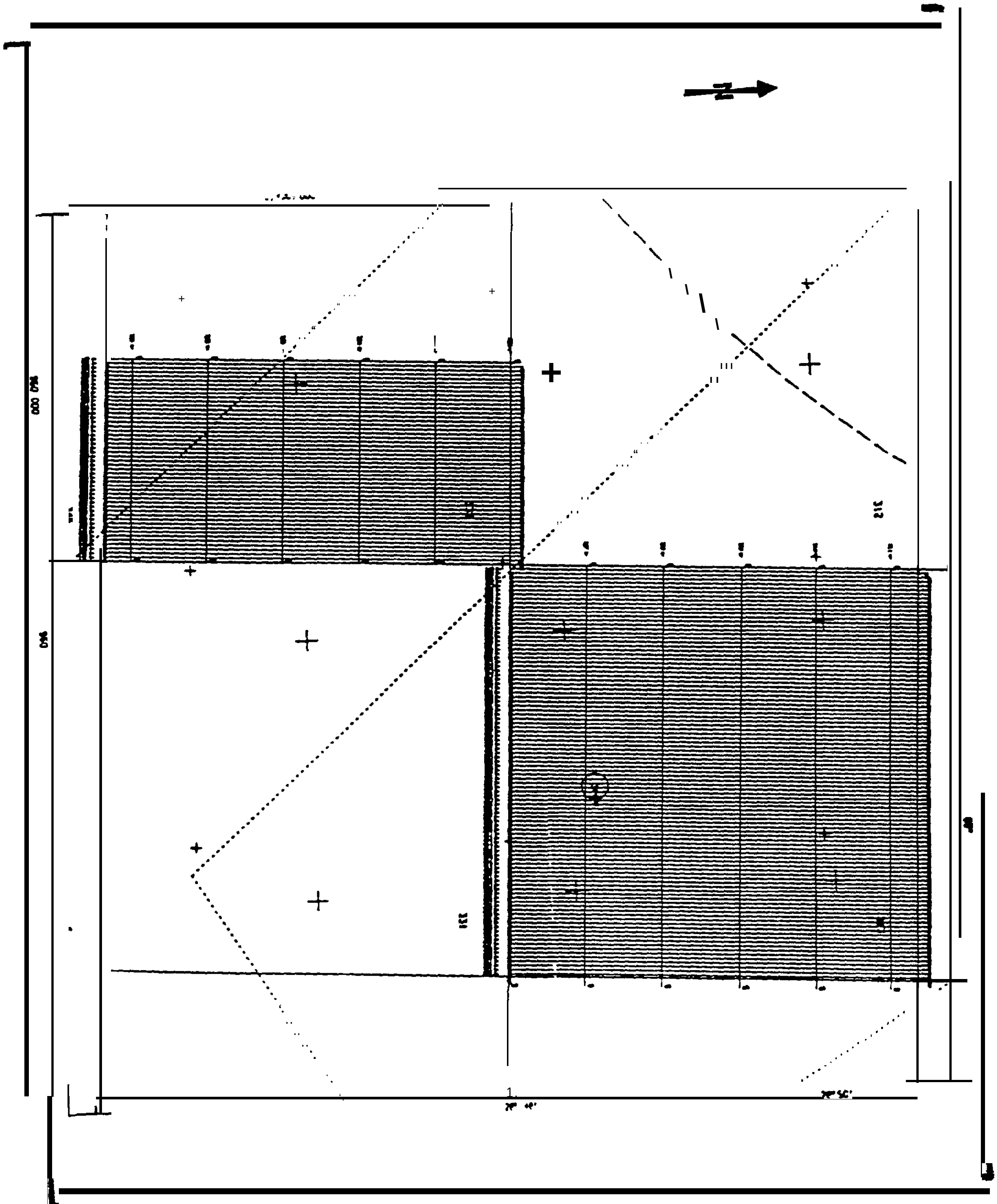


FIGURE II-57. Preplotted cruise tracks, GA 313 and GA 332.

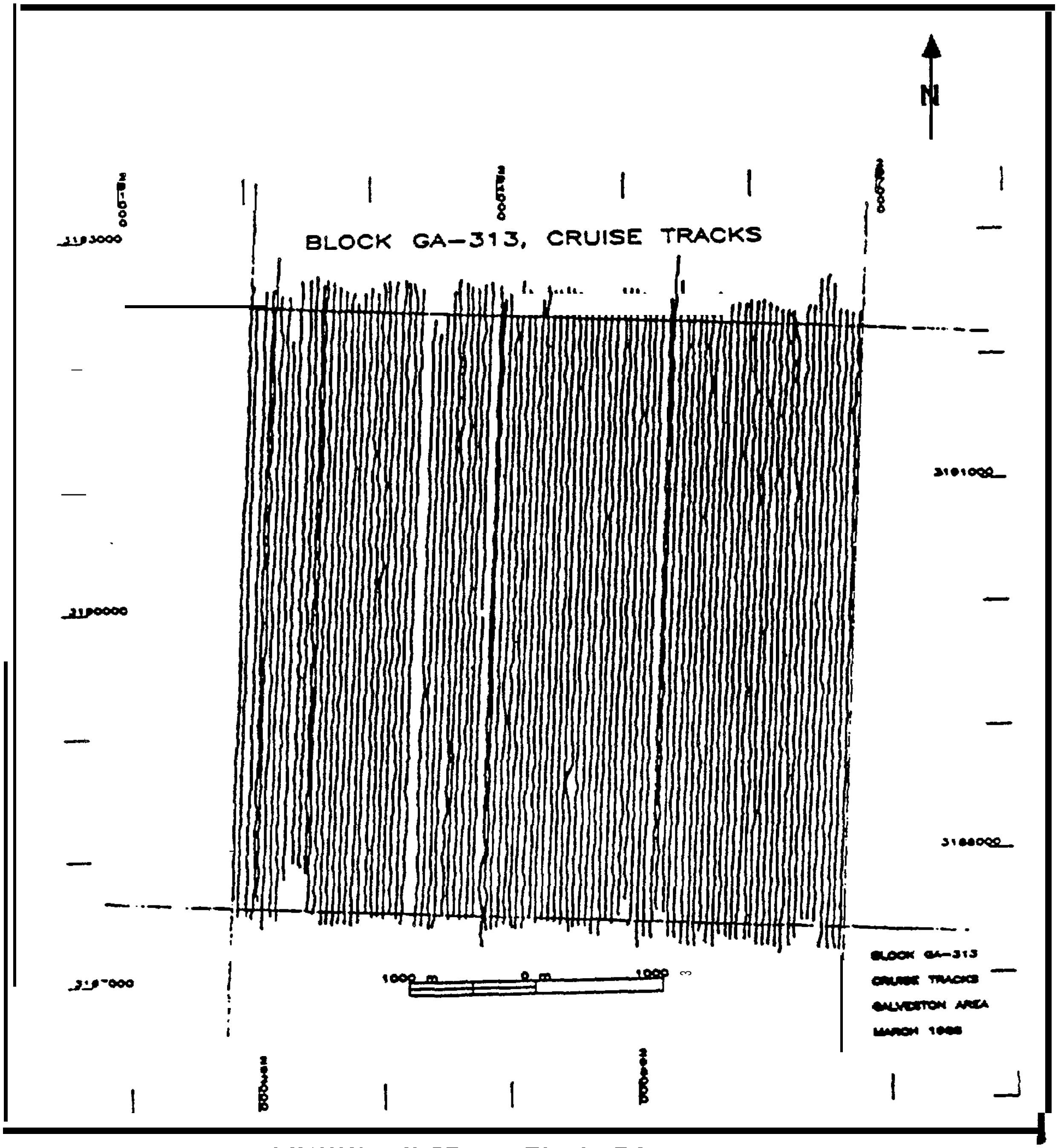


FIGURE II-58. Block GA 313 cruise tracks.

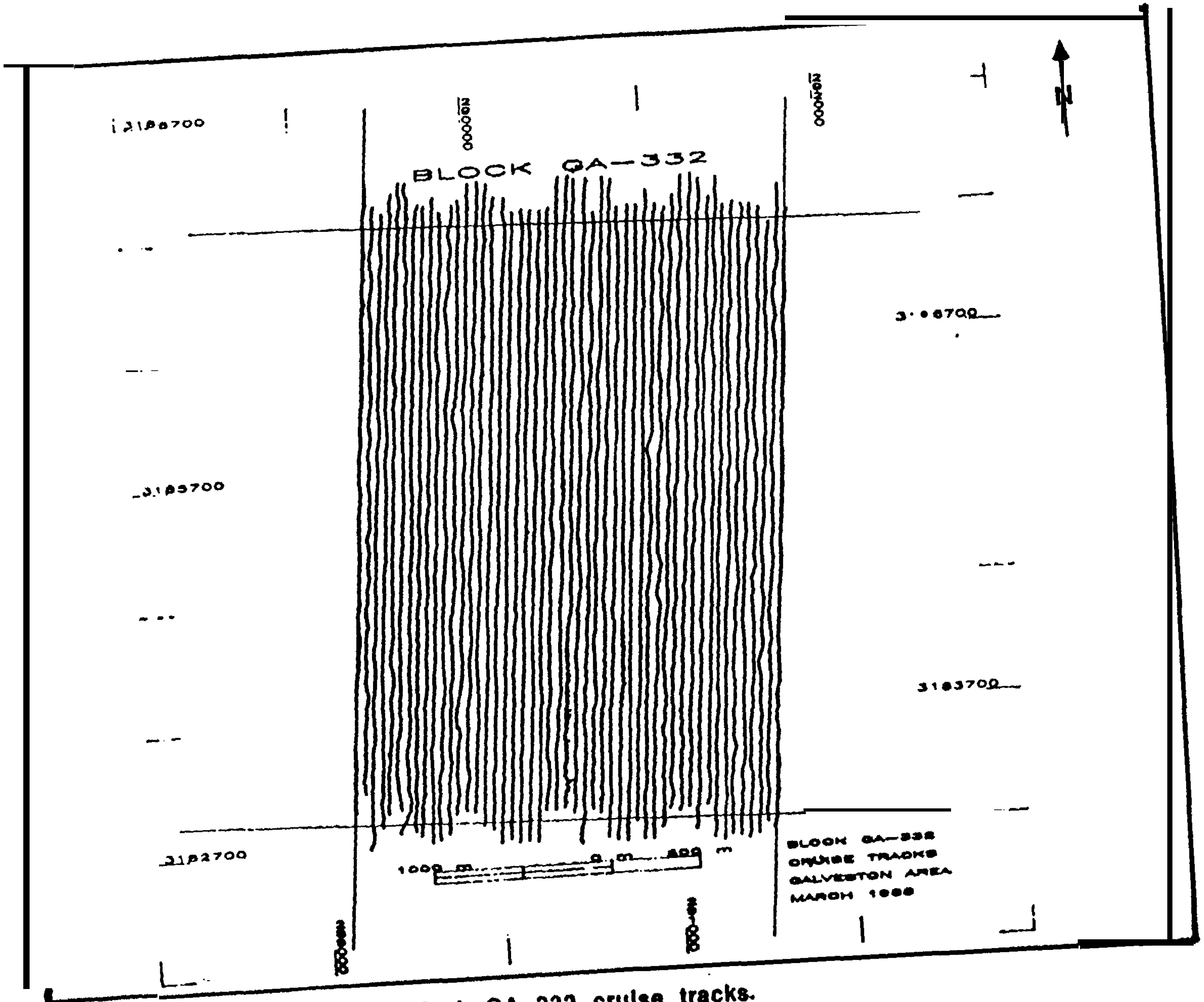


FIGURE II-59. Block GA 332 cruise tracks.

Table II-24.

SUMMARY OF GEOGRAPHIC CONTROL DATA.

a. CONTROL POINTS USED FOR RESURVEY OF BLOCKS 313 & 332

Station	Location	Geographic Coordinates	UTM Coordinates (meters)		State Plane Coordinates [feet)	
			x=E	y=N	x=E	y=N
TR 724	SFX 31OL	ø = 28°50' 26.143" x = 95°14'22.683"	281491.71	3192210.59	3203652.5	385586.3
TR 764	LORAC	ø = 28°58'22.395" x = 95°15'58.692"	279169.52	3206922.22	3193583.6	433386.5
TR 744	COAST G.	ø = 28°56'27.407" x = 95°18'02.962"	275736.09	3203447.04	3182919,4	421428.6
E TOWER	LORAC	ø = 28°58' 22.401" x = 95°15'58.704"	279169.19	3206922.41	3193582.5	433387.1
C.E. FH2	COAST G.	ø = 28°56' 28.016"	275622.16	3203467.23	3182673.87	421482.36

b. LOCA!ITON SENTERE DFORTHEMICROWAV EREMOTES

Remote	Easting	Northing
724	281491.7	3192210.6 (meters)
744	275736.1	3203447.0
764	279169.5	3206922.2

c. CALIBRATION FACTORS ENTERED FOR EACH REMOTE

Remote	Calibration Factors	Height Meters	Reference-x Reference-y
724	755	5	281491.7 192210.6
744	800	5	275736.1 203447.0
764	800	13	279169.5 206922.2

13.2 Groundtruthing Activities

13.2.1 Techniques of Relocation and Recording

13.2.1.1 GA 324

The instrumentation utilized in the resurvey of this lease block was redeployed for relocation and groundtruthing with the exception of the side-scan sonar. This latter instrumentation was not used because none of the sites selected for groundtruthing were side-scan sonar contacts or contacts associated with magnetic anomalies.

The position of the site was relocated and a marker buoy dropped. Typically, the position marker was deployed after the location was refined instrumentally. The anomaly sites selected for groundtruthing in GA 324 were difficult to relocate instrumentally so the position determined from the lease block resurvey was relied on for deployment of the marker buoy.

Navigation and magnetic data were acquired on three transects of the site. One line was run directly over the location with two offsets of 15 to either side of the feature. Once logged, all tow cables were recovered and divers deployed.

Divers established a temporary datum at the marker buoy anchor. From this station, an area of over 50 m diameter was examined by swimming a circular search pattern increasing the diameter with each complete rotation. Typically, an increment of 3-5 m was used as visibility at the bottom rarely met or exceeded this limit. Divers used the underwater metal detector during the circle search.

Any source for an anomaly or side-scan sonar contact was located, measured, and video documented if visibility conditions aHowed. Divers used standard surveyor tapes or pre-measured lines to gauge their progress. For video work, a JVC portable VCR, VHS-C format was used. Video was selected routinely over still photographic techniques because of poor visibility due to the nephloid layer so prevalent in this part of the Gulf (McGrail and Carries 1983).

13.2.1.2 GA 313 and GA 332

Most of the Task II groundtruthing activity took place in these blocks. In these blocks the side-scan sonar was utilized extensively.

As with GA 324, the site chosen to be groundtruthed was relocated using the same navigation system used for resurvey. A marker buoy was dropped after data for signature characterization analyses was taken. In some instances, data was taken and the site not examined by divers. Such a decision was made after analysis of the instrumental data. Typically, only magnetic anomalies were the subject of such re-examination. The reason for this was an economic one--only about 20 sites could be effectively examined in the field study period so only sites with a reasonable chance of being identified by divers were groundtruthed. By experience, we found that anomalies without an associated side-scan sonar contact were buried and had a less than 30 percent chance of identification by divers. Once the divers were deployed, the techniques used were similar to those used at GA 324.

13.3 **Results and Resurveys**

13.3.1 *Anomaly Comparisons - Original Survey and Resurvey Results*

13.3.1.1 GA 313 Results

The resurvey of GA 313 provided comparative data for the category of a developed lease block. Completely resurveyed, a total of 70 lines (exclusive of 27 lines) at the 50 linespacing interval produced 85 magnetic anomalies, compared to the original survey result of 17 anomalies. (Table II-25) (Figure 11-60a). This number is conservative due to the reduction of our sample from 97 to 70 due to excessive noise or other problems (such as complete loss of one line due to a formatting error on a diskette), Inspection of Table II-25 shows the spatial relationship of "bad" or noisy lines to those used in our analyses. In one instance lines 178 and 179 the linespacing is reduced to 150 m and only in one other case, lines 186-189, does the elimination of data leave a gap of 200 m between contiguous lines. This leaves nearly 75 percent of the block surveyed at the 50 m interval and nearly 90 percent at the 100 m interval. Similarly, the 100 linespacing produced 65 magnetic anomalies. An interesting result is the increase in anomalies seen for the 50 m linespacing interval data of the resurvey (59) as compared to the original survey (17). This was assumed to relate to oil and gas development in GA 313 since the original survey.

Table II-25.

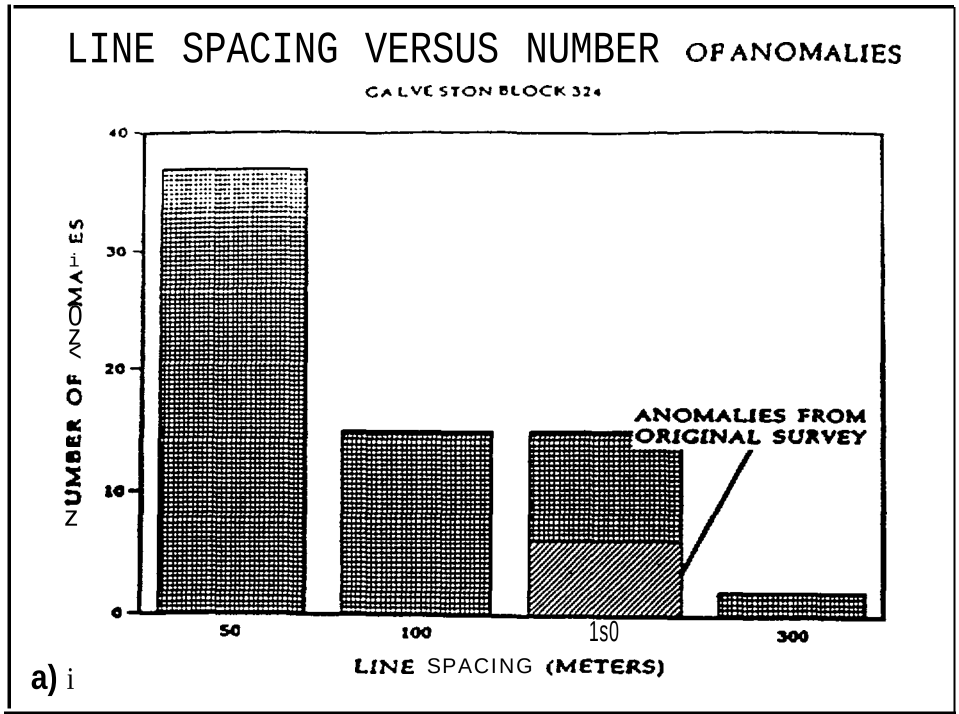
GA 313: PERCENTAGE OF ANOMALIES AT VARIOUS LINE SPACINGS; 50 AND 100 METERS.

Line	50 Meters	100 meters
148	2	
149		
150	1	-
151	0	0
152	2	
153	.	
154	0	
155	0	0
156	4	-
157	2	2
158	0	
159	0	0
160	1	.
161	1	1
162	1	
163	0	0
164	3	
165	5	5
166	1	
167	3	3
168	3	
169	0	0
170		.
171	4	4
172	3	
173		
174	3	
175	5	5
176	2	
177	0	0
178		
179		
180	4	
181	4	4
182		
183	1	1
184	3	-
185	3	3
186		.
187		
188		
189	2	2
190	2	-
191	2	2
192	0	-
193	0	0
194	1	

Table II-25
(continued).

195	-	
196	2	
197	5	5
198	4	-
199	6	6
200	7	
201	4	4
202	1	-
203	5	5
204		
205	3	3
206	.	
207	.	
208	-	-
209	2	2
210	0	
211	.	-
212		
213		
214		
215	4	4
216	.	
217	-	
218	-	
219	3	3
220	3	
221	1	1
222	4	
223	4	4
224		-
225	.	-
226	-	-
227	4	4
228	5	-
229	1	1
230	1	
231	2	2
232	2	.
233	2	2
234	2	
235	3	3
236	1	.
237	1	1
238	2	.
239	1	1
240	.	
241	3	3
242	2	-
243	1	1
244	-	-

Σn @ 50 meters: 116 minus 31 duplications = 85 anomalies
Σn @ 100 meters: 85 minus 20 duplications = 65 anomalies
Original Survey n = 17



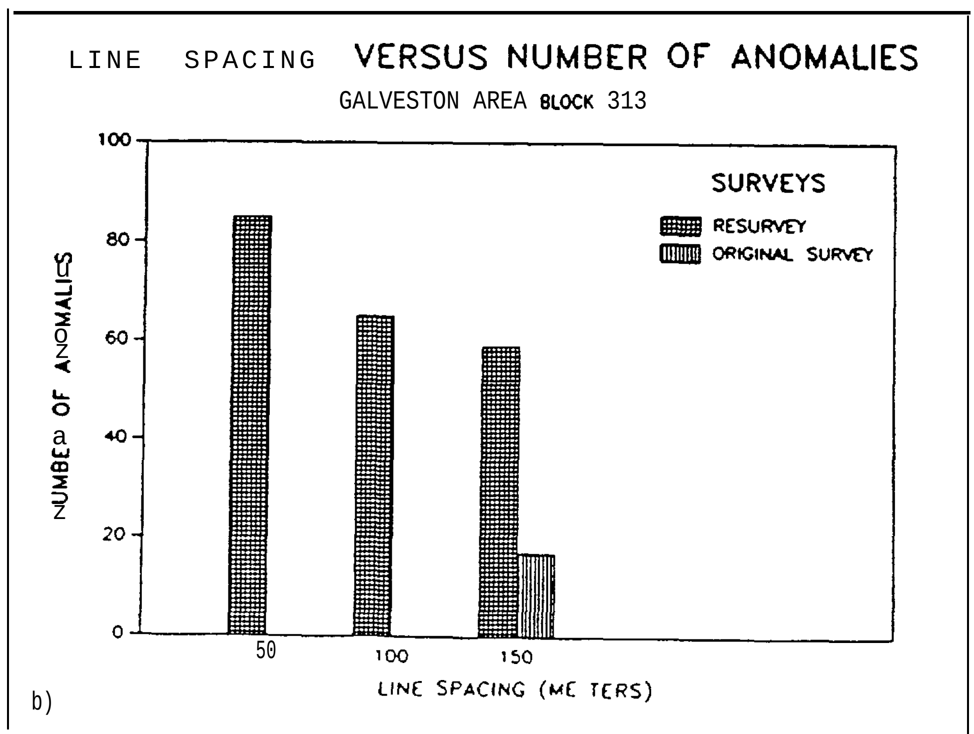


FIGURE II-60. **(a) Linespacing versus number of anomalies, GA 324**
(b) Linespacing versus number of anomalies, GA 313

13.3.1.2 GA 324 results

The resurvey of GA 324 provided much of the data for the undeveloped lease block. Of the 61 survey lines, a total of 40 were used for this analysis. Lines 100-109 and 151-161 were of marginal quality because of a high signal-noise ratio. All lines left in the sample were contiguous and allowed a complete evaluation of one-half the block at the required linespacings. The data utilized were high quality and represented a coverage area of the original survey where six of the eight original anomalies were found.

Thirty-nine (39) anomalies were detected during resurvey at the 50 linespacing interval (Table II-26) (Figure 11-60 b). Twenty-three (23) were located at the 100 linespacing interval. No anomalies were detected on adjacent survey lines.

13.3.1.3 **GA 332 results**

This undeveloped block was originally surveyed along diagonal tracks that covered only that portion outside the active shipping fairway. Resurvey covered that portion within the fairway along north-south survey tracks (Figure II-57). Intercomparison suffers somewhat although no anomalies were detected in the original survey. Resurvey covered about 25 percent of the original survey tracks in the southwest portion of the block.

Resurvey of the eastern half of GA 332 detected 57 anomalies at a 50 linespacing interval and 36 at a 100 m linespacing interval (Table II-27). Most of this area is an active shipping fairway.

13.3.2 Correlation of anomaly locations, amplitude, duration, and signature between the original and new surveys.

13.3.2.1 GA 313 results

Anomaly locations - Six possible relocations of seventeen originally reported anomalies were made during resurvey. Possible reasons for this discrepancy are discussed in Section 14.2. Correlations of between our position and the original survey were difficult because grid coordinates in a Lambert projection were used on the original survey and geographic coordinates (Lambert) and grid coordinates (Universal Transverse Mercator, UTM) were used in the resurvey.

<u>Original Survey</u>	<u>Resurvey</u>
line 1 S, Fix Pt. 8.2	line 149 N, Fix Pt. 155
line 8 N, Fix Pt. 8.2	line 172 S, Fix Pt. 108
line 11 S, Fix Pt. 3.9	line 181 S, Fix Pt. 111 .2*
line 16 N, Fix Pt. 5.7	line 193 N, Fix Pt. 160
line 35 E, Fix Pt. 25.1	line 181 S, Fix Pt. 141
line 38 W, Fix Pt. 21.1	line 196 S, Fix Pt. 141
line 40 W, Fix Pt. 17.8	line 204 N, Fix Pt. 100*

*same anomaly

Table II-26.

GA 324: PERCENTAGE OF ANOMALIES AT VARIOUS LINE SPACINGS; 50 AND 100 METERS.

Line	50 Meters	100 Meters
110	1	
111	0	0
112	1	
113	2	2
114	0	
115	0	0
116	2	
117	2	2
118	0	
119	1	1
120	0	
121	1	1
122	0	
123	1	1
124	0	
125	0	0
126	3	
127	2	2
128	0	.
129	4	4
130	1	.
131	0	0
132	0	
133	1	1
134	0	
135	0	0
136	0	
137	1	1
138	0	
139	2	2
140	0	.
141	1	1
142	0	
143	2	2
144	1	
145	0	0
146	1	
147	0	0
148	4	.
149	3	3
150	3	

$\sum n$ @ 50 meters = 39 (no anomalies on adjacent lines)
$\sum n$ @ 100 meters = 23 (no anomalies on adjacent lines)

Original Survey n=8 (lines 100-161, n=6)

Table II-27.

GA332: Percentage of anomalies at various line spacings; 50 and 100 meters.

Line	50 meters	100 meters
100	0	-
101	.	0
102	0	-
103	0	0
104	0	-
105	0	0
106	2	
107	.	-
108	3	
109	0	0
110	0	
111	1	1
112	0	-
113	1	1
114	1	
115	0	0
116	0	-
117	0	0
118		-
119		-
120	4	
121	3	3
122	0	
123		
124	0	0
125	0	
126	0	0
127	0	
128	1	1
129	2	
130	3	3
131	3	-
132	2	2
133	.	
134	2	2
135	.	
136	.	-
137	3	-
138	4	4
139		
140	4	4
141	3	
142	3	3
143	.	
144	5	5
145	.	

Table II-27
(continued)

146	.	-
147	2	
148	2	2

$\sum n$ @ 50 meters = 90 minus 13 duplications = 77 anomalies
$\sum n$ @ 100 meters = 36 minus 6 duplications = 30 anomalies
Previous survey = O anomalies

Amplitude - For these possible correlations the maximum amplitude for the anomalies were (in nanoteslas):

Original Survey	Resurvey
line 1 S, 26 nT	line 149 N, 21 nT
line 8 N, 65 nT	line 172 S, 34 nT
line 11 S, 7 nT	line 181 S, 12 nT
line 16 N, 40 nT	line 193 N, 12 nT
line 35 E, 10 nT	line 181 S, 12 nT
line 38 W, 145 nT	line 196 S, 28 nT
line 40 W, 12 nT	

Duration-The duration of the anomalies is compared in signature widths.

Original survey	Resurvey
line 1 S, 23 m	line 149 N, 3sec, 8 m
line 8 N, 15 m	line 172 S, 1.5 see, 4 m
line 11 S, 30 m	line 181 S, 4.5 see, 12 m
line 16 N, 23 m	line 193 N, 3 sec, 8 m
line 35 E, 15 m	line 181 S, 4.5 sec., 12 m
line 38 W, 8 m	line 196 S, 15 sec., 38 m
line 40 W, 15 m	

Signature - The original survey report gives no indication as to the signature--dipolar, monopolar, etc.--of the reported anomalies. The resurvey signature descriptions are:

Anomaly	Signature
line 149 N	monopole, negative
line 172 S	monopole, positive
line 181 S	multipole, positive/negative
line 193 N	monopole, negative
line 196 S	monopole, negative (very broad)

13.3.2.2 GA 324 results

Anomaly locations - Three possible relocations of six originally reported anomalies were made. The associations between these anomalies of the two surveys are:

Original Survey	Resurvey
line 39 N, Fix Pt. 120.35	line 119 S, Fix Pt. 111.5
line 42 N, Fix Pt. 1 1 0.80	line 129 S, Fix Pt. 120.8
line 47 N, Fix Pt. 105.40	line 144 N, Fix Pt. 127.9
line 146 S, Fix Pt. 127.4	

Amplitude - For these possible correlations the maximum amplitude for the anomalies were (in nanoteslas):

Original Survey	Resurvey
line 39 N, 6 nT	line 119 S, 18 nT
line 42 N, 4 nT	line 129 S, 7 nT
line 47 N, 5 nT	lines 144, 146, 7 nT, 11 nT

Duration - The duration of the anomalies are difficult to compare with the original survey. It is assumed fix point intervals on the original survey were 1500 m Interpolation based on this assumption yields the linear duration. Duration time is difficult to estimate without a good estimate of vessel speed. Resurvey anomaly durations are given in meters and seconds as vessel speed was constantly monitored.

Original Survey	Resurvey
line 39 N, .30 (45 m)	line 119 S, 6 see; (15 m)
line 42 N, .20 (30 m)	line 129 S, 6 see; (15 m)
line 47 N, .30 (45 m)	line 144 N, 4 see; (10 m)
line 146 S, 14 see; 116 ft.(35 m)	

Signature - The original survey report gives no indication as to the signature--dipolar, monopolar, etc.--of the reported anomalies. The resurvey signature descriptions are:

Anomaly	Signature
line 119 S	monopole, positive
line 129 S	monopole, positive
line 144 N	monopole, negative
line 146 S	multipole, positive/negative

Comments - Of the six anomalies, five appear to be verified. The anomalies reported in the original survey, line 11 S and line 35 E, are very close in position. Given the close proximity, we treated this as one anomaly, line 181 S (our survey). To reduce possible error in intercorrelation of positions between surveys we examined adjacent lines (e.g. for the anomaly on 181 S we looked at data from lines 180 and 182).

13.3.2.3 GA 332 results

No intercorrelation between surveys possible due to absence of anomalies on original survey.

13.3.3 Number of new magnetic anomalies and/or side-scan sonar contacts recorded within the developed lease block, GA 313, and the location of these anomalies relative to oil and gas structures.

The resurvey of block GA 313 produced 68 new anomalies at a 50 m linespacing. The distribution of anomalies before noise filtering or removal of adjacent survey line data is seen in Figure II-61. The central portion of the block has the greatest concentration of anomalies with the highest density seen near the production well now in the block. The well itself is the principal anomaly but all the groundtruthed side-scan targets were within 1,000 m of the platform. Only magnetic anomalies were seen and groundtruthed outside the 100 m diameter. The results tend to support the notion of a “toss zone” but the debris seen within this area may not directly result from oil and gas activities. The objects found near the well site could have come from commercial and sport fishing activities. The refrigerator found on line 202 could have fallen from a trawler while the barrels seen on lines 207 and 205 could have fallen from supply boats or from fishing craft. A pipe found on line 229 is clearly related to oil and gas activities.

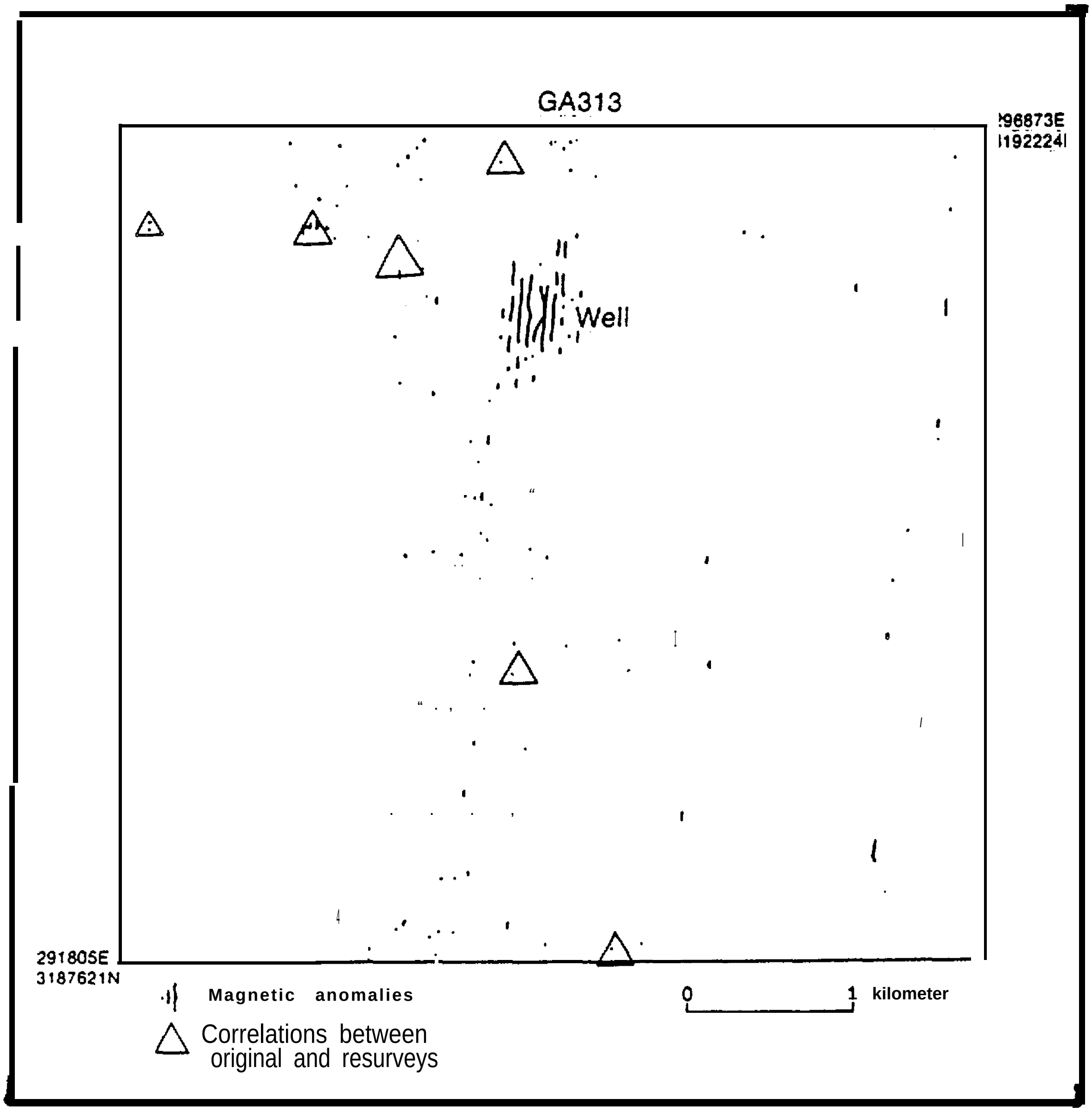


FIGURE II-61. Increase of anomalies in GA 313, unfiltered data.

Whether oil and gas activities directly generate this marine debris is not clear from this survey. What is clear are the following:

a. an increased number of anomalies after block development;
b. all observed side-scan sonar targets are post-development; and
c. the anomalies and side-scan sonar targets concentrate near the oil and gas structure.

13.4 Groundtruthing Characterization of Side-Scan Sonar Contacts and/or Magnetic Anomalies - Instrumental and Observational Data

13.4.1 *Magnetometer and/or side-scan sonar data collected at linespacing of 50 m or less*

Summary data on the results of relocation and groundtruthing efforts are given in Table II-28. Characterizations of individual side-scan sonar and/or magnetic anomaly sites appear later in this report and in Appendix K. We followed formats originally used by Arnold (1980) Clausen and Arnold 1975; Arnold 1979, 1982; Clark 1986; Scollar, et. al. 1986; and Gearhart 1988. The attempt is to present empirical data which demonstrates specific causes for a variety of anomaly types - shipwrecks to modern debris. Arnold (1 980) makes no attempt at any data synthesis as it correlates among theoretical expectations, anomaly characteristics and their sources. It is, however, one of the first expositions of the value of groundtruthing in evaluating anomalies.

Arnold (1980) discusses a problem in the use of earlier magnetometers which involves the non-detection of rapid scale shifts. When a strip chart recorder was used to record magnetometer data, only the trace, corresponding to scale ranges was often printed. When the analog record shifted with a large anomaly reading, the chances were good that one would not detect the shift.

Recent improvements in analog recorders, such as that used on the present survey avoid this problem by overprinting the actual magnetic reading on the record simultaneously with the profile trace (Table II-28). Our methodology has taken this one step further by the extra capability of recording the digitized data to magnetic tape via a serial BCD interface to a microcomputer. This eliminates the non-detection of sudden scale shifts in high gradients as well as provides the opportunity to record ancillary survey data such as time and position with the magnetometer readings. The full utility of this method can be seen in the computer based manipulation and processing of survey and groundtruthing data for visual display and analysis.

Table 11-28.

SUMMARY DATA - RELOCATION AND GROUNDTRUTHING STUDIES.

Sites Resurveyed	Sites Relocated*	Anomalies and/or Targets Logged for Data
101 (GA332)	101 (GA332)	101 (GA332)
106 (GA332)	104 (GA332)	107 (GA332)
107 (GA332)	110 (GA324)	110 (GA324)
108 (GA332)	116 (GA332)	116 (GA332)
109 (GA332)	125 (GA332)	125A (GA332)
110 (GA324)	137 (GA332)	125B (GA332)
116 (GA332)	148 (GA332)	125C (GA332)
125 (GA332)	152 (GA332)	125D (GA332)
137 (GA332)	163 (GA332)	137 (GA332)
148 (GA332)	164 (GA332)	148 (GA332)
149 (GA313)	175 (GA313)	152 (GA313)
150 (GA313)	185 (GA313)	164 (GA313)
152 (GA313)	202 (GA313)	175 (GA313)
163 (GA313)	203 (GA313)	185A (GA313)
164 (GA313)	205 (GA313)	185B (GA313)
175 (GA313)	229 (GA313)	185C (GA313)
185 (GA313)	305 (GA332)	202 (GA313)
192 (GA313)		205A (GA313)
194 (GA313)		205B (GA313)
197 (GA313)		207 (GA3 13)
202 (GA313)		229 (GA3 13)
203 (GA3 13)		305 (GA332)
205 (GA313)		
207 (GA313)		
229 (GA313)		
231 (GA313)		
305 (GA332)		

*Only sites that could be relocated on more than one resurvey line are listed. Some features, particularly magnetic anomalies, could be found on a northward or southward resurvey line but not on the opposite line direction. The objects were there but could not provide adequate detail for mapping requirements. A few features could not be relocated at all.

ANOMALIES/SIDE SCAN TARGETS GROUND-TRUTHED

101 (GA332)
107 (GA332)
125A (GA332)
125B (GA332)
125C (GA332)
125D (GA332)
152 (GA313)
163 (GA313)
164 (GA313)
175 (GA313)
185A (GA313)

Table II-28
(continued).

185B (GA313)
185C (GA313)
202 (GA313)
205A (GA313)
205B (GA313)
229 (GA313)
305 (GA 332)
110 (GA324)

ANOMALIES/SIDE SCAN TARGETS IDENTIFIED

152 (GA332)
163 (GA313)
164 (GA313)
175 (GA313)
202 (GA313)
205A (GA313)
205B (GA313)
229 (GA313)
305 (GA332)
107 (GA332) Tentative

14.0 SUMMARY AND CONCLUSIONS - TASK II

14.1 Magnetic Anomaly Characterization - general parameters

All sites evaluated by groundtruthing were modern marine debris. The results directly aid in evaluating the instrumental signatures obtained in the resurveys.

14.1. i. Pattern Recognition in Instrumental Signatures and the Correlation with Shipwrecks and/or Modern Marine Debris.

Two major areas of concern for anomaly characterization are: (1) "masking" of shipwrecks by the proliferation of modern marine debris, associated with oil and gas development; and (2) the modeling of single or multiple component magnetic signatures to allow the development of an interpretative framework to help discriminate between remote sensing data representative of modern marine debris and the remains of historic shipwrecks.

Current survey methodology and subsequent characterizations lack spatially adjacent magnetic data such that contour plots can be prepared. Currently, only single line profiles of anomalies can be evaluated as to the strength and duration of the signature or signatures. Linington (1966) suggested an approach to the analysis of such profile data by deducing anomaly shapes using a simplified series of approximations based on magnetic theory. Few analyses followed this early effort in the presentation of magnetic data in graphical form.

The effectiveness of a particular survey intensity as a discovery technique greatly depends on the size and visibility of the things being sought (Doelle 1977). Shipwrecks are discrete sites but in relation to single artifacts or small assemblages they are "large anomalies." This largeness must be viewed relative to the survey area itself. Nominally, the range of vessel size, by area, is from a few square meters to in excess of 2,000. This is small given the size of the Gulf of Mexico or even a lease block (27.8 km). Thus, it is difficult to expect any magnetic intensity detected on one line to be detected at any strength on an adjacent line space 150 m away. This follows from the simple physical relation of magnetic strength to distance given by the equation:

$$\vec{T}_x = \frac{\vec{M}_f}{d^3} \qquad \text{(Eq. 1)}$$

Where T = the anomaly magnetic strength
M = the dipole moment in cgs units and that of a localized field
d = the distance from the sensor to the anomaly in centimeters

As the distance increases from the object the intensity of the magnetism decreases with the cube of the distance. This phenomenon alone allows detection of only the largest magnetic features (five tons of iron) on two adjacent lines at 150 m offset. A further complicating factor is the direction of the earth's magnetic field and its vectorial relation with that of the object. By simple physics, these components increase or decrease the magnetic strength of the signal depending on orientation of the object and local field. The use of side-scan sonar in concert with the magnetometer is considered a form of redundancy to mediate the loss of magnetic strength by a broader acoustical scan of the bottom.

Figure II-62 illustrates the best case for either detection system. It is the liberty ship B.F. SHAW sunk as an artificial reef off Freeport, Texas. Unfortunately, this example is the

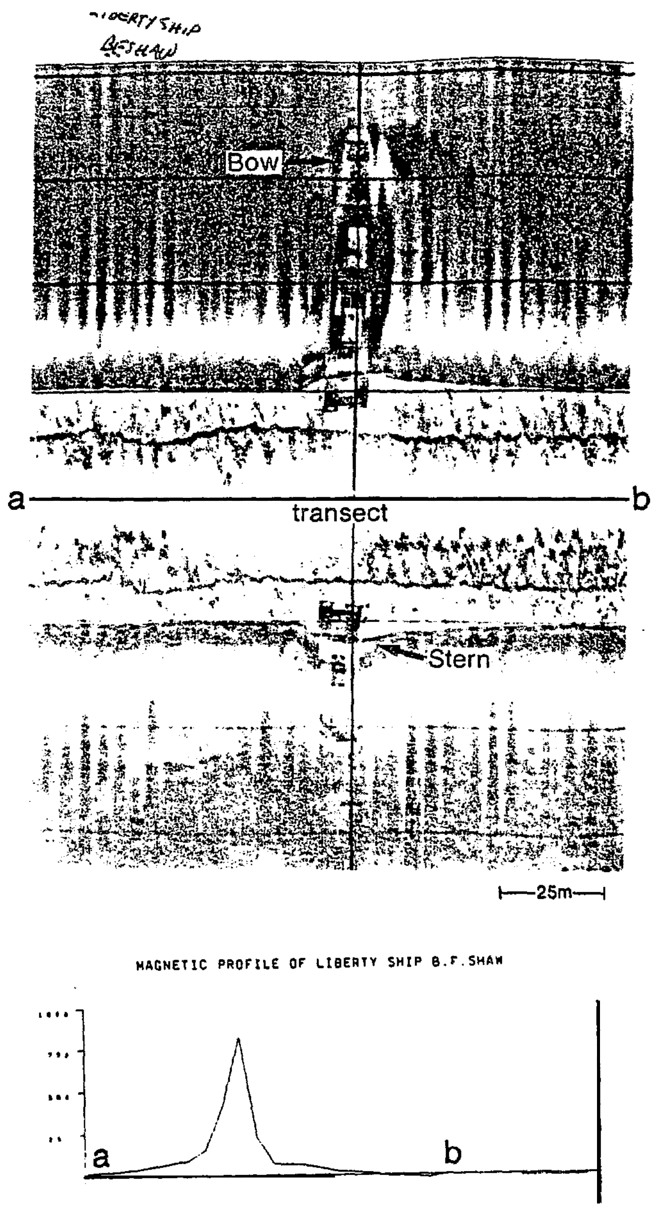


Figure 11-62 Sonogram and magnetic profile of the Liberty Ship B.F. SHAW

exception rather than the rule. We cannot expect such a concentration of metallic mass, size, and preservation from earlier vessels. The liberty ship is over 100 m long and all metal. Such an object falls in the 50 m overlap zone for adjacent tracks on a 150 m linespacing. However, if the vessel was less than 50 m in length, as was common for sailing ships, it would not be detected by the side-scan sonar at the 100 m scale. An increase of instrumental scan range to 200 m would only loose the resolution of smaller features.

A particular problem with the intercorrelation of acoustical and magnetic data on anomalies is related to range. It is believed that fine grained and short-ranged sweeps by the sonar will provide greater resolution of the anomalies by reducing scale size on the monographs. The percentage of anomalies can be determined and compared for specific types of anomalies that partition into modern debris, modern shipwrecks or historic shipwrecks. Arnold (1976, 1977, 1978, 1979, and 1980) showed that on 47 significant magnetic anomalies in Texas waters, only 13 percent, or six cases, showed debris above the bottom and hence detectable with side-scan sonar. As one study of block GA 313, 10 side-scan targets proved to produce eight anomalies upon groundtruthing. Two of these targets were bottom disturbance due to anchoring or mooring activities and produced no detectable anomalies. The rest of anomalies examined in GA 313 had no associated side-scan sonar targets.

The search for indicator variables or patterns of magnetic data can only raise present predictive confidence, Variables in the magnetic data for ‘analysis include but are not’ limited to:

a. duration;
b. amplitude;
c. shape;
d. sign; and
e. frequency.

The characteristics of magnetic data were treated by authors such as Aitken (1974), Tite (1 972) and Breiner (1973). In sum, magnetic data has two principal aspects, a spatial aspect and a spectral aspect. An early presentation of the spatial character of magnetic data is shown in Figure II-63. In succeeding years computer graphics techniques have been applied for the visual, qualitative display of this data.

While informative, these graphical presentations have not led to reliable methods of determining the nature of the anomalies detected by magnetic survey (Baker 1982). These two- and three-dimensional presentations of magnetic data have collapsed several parameters of dimensions into a visual representation analogous to a diversity index. These indices, by their nature, are dimension-less and reduce masses of numbers into a single parameter (Green 1979). Information may be lost in the spatial image. Variables such as amplitude, frequency, wavelength, and shape may be more meaningfully evaluated by such composite approaches (Green 1979) than by considering them as separate index measures.

As pointed out in our introductory remarks, current methodology used in lease block surveys for anomaly analysis is inhibited by the lack of original data in leasee reports. This original data can be called for by agency professionals reviewing the leasee reports and has become common practice. No comparative body of data have emerged from the many surveys done where the lease stipulation was invoked.

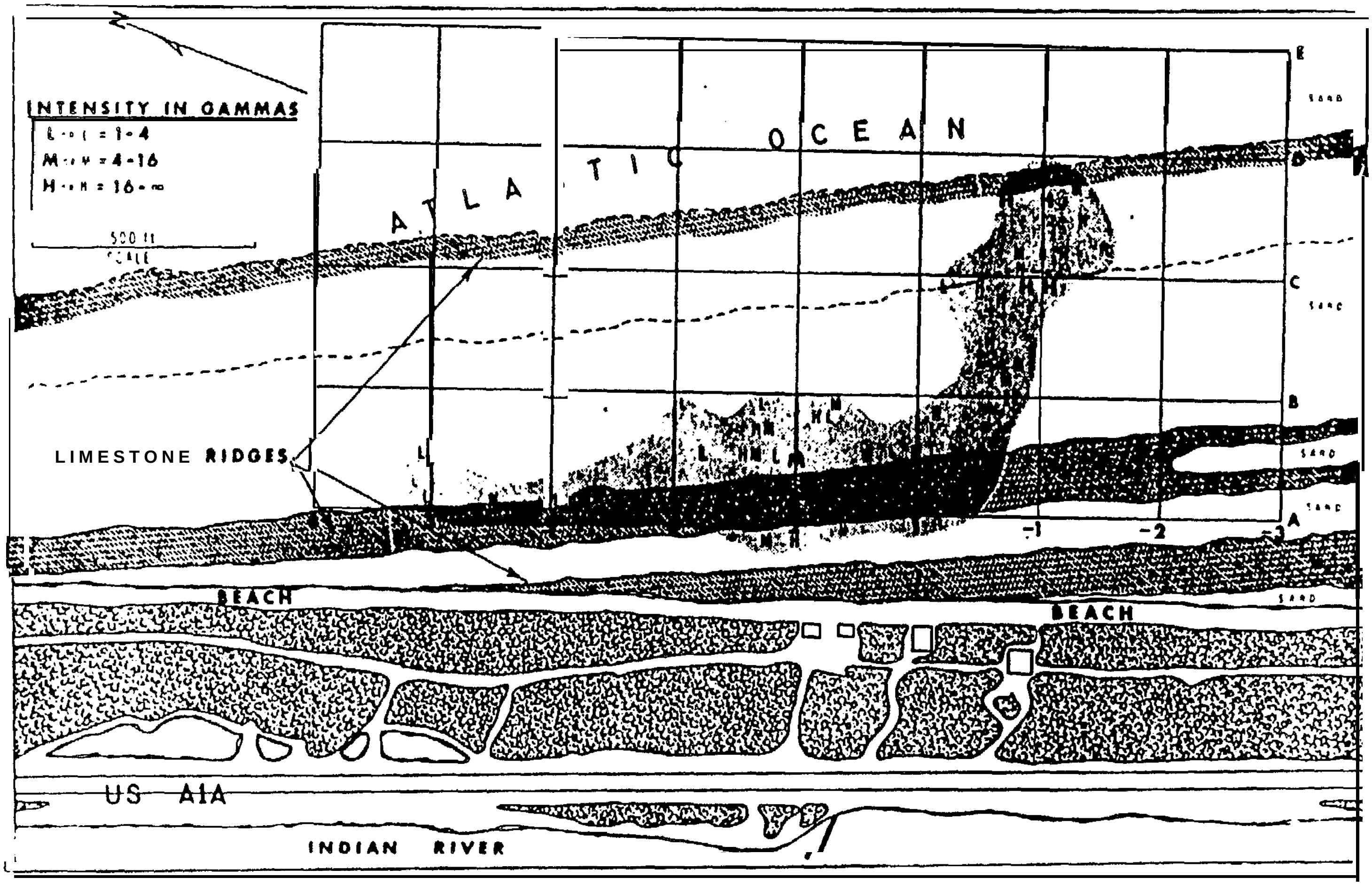


FIGURE II-63. **Two-dimensional graphical presentation of magnetic data for a 1715 shipwreck,** 14.1.1.1 Duration

Duration is more properly called anomaly width but has also been described as the wavelength (Breiner 1973). If we treat the wavelength as the total observed perturbation created by a magnetic feature, then the duration can be measured in temporal units. In some instances it is reported in spatial units. In Figure II-64, the duration t of the anomaly would be the time necessary for the wavelength to reach a maximum, a minimum and return to ambient field strength. Typically, dipolar anomalies exhibit such behavior where a maxima and minima are seen before the ambient level is finally reached.

In the case of monopolar anomalies, the anomaly may not exhibit a minima, showing only an inflection about the maximum. Here the duration is simply read as the time, t, from the anomaly's departure from ambient field, t_1, to its return, t_2.

The expression of duration as a distance has not been regularly done in lease survey reports. Duration reported as time does not allow the utilization of the width of the wavelength to determine even the depth of buried anomalies by the "full width-half maximum" (FWHM) rule of thumb (Weymouth 1986; Breiner 1973). Utilizing the maximum value of the anomaly, and assuming a simple shaped source (sphere, etc.), a depth estimate within 10-50 percent can be obtained (Breiner 1973). In large portions of the Gulf's continental shelf, most historic materials are not too deeply buried (2 m) and this empirical formula can be roughly used to estimate distance to the source. Even this simple technique cannot always be used when some reports cite duration as a function of time only.

The importance of duration as a quantitative descriptive parameter is illustrated by Table II-29 taken from Garrison (1986) where within 100 m of a shipwreck the anomaly duration is constant.

TABLE II-29

WILL O'THE WISP **Study: Anomaly Duration Related To Distance From The Source**

Line #	Time (see)	Distance (m)
1	130	0
2	140	50
3	150	75
4	160	100
5	70	125
6	40	150

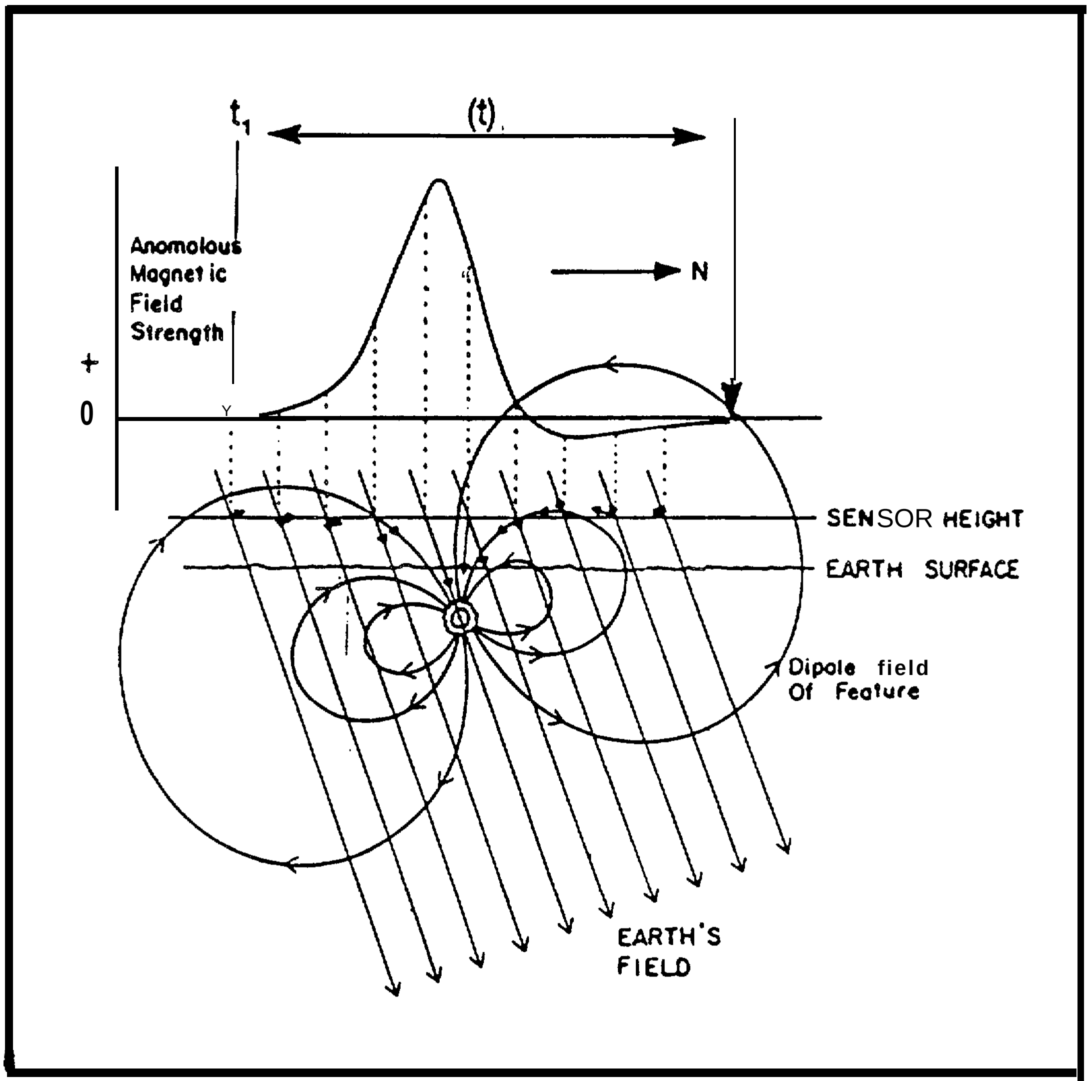


FIGURE II-64. **Schematic representation of the relationship of anomaly amplitude, shape, duration and field orientation.**

14.1 .1.2 Amplitude

The basic expression for estimating the maximum amplitude of any anomaly is the general form of Equation 1 or:

$$\vec{T} .= \frac{\vec{M}}{d^n}$$

(Eq. 2)

Where T, M, and d = the same as Equation 1

The falloff rate, d, as a function of n, distance, is expressed more generally as n. Typically n equals 3 for dipoles and n equals 2 for monopoles.

The relative amplitude of an anomaly is a function of the earth's field direction, the configuration of the source, and any remnant magnetism (Breiner 1973, 1975). The maximum amplitude is largely a function of burial depth and magnetic contrast. Magnetic contrast is the result of the magnetization of the object sometimes described as remnant magnetism. This permanent magnetism is a property of the material together with its thermal and mechanical history. In metallic iron the oxides haematite (Fe_2O_3), magnetite (Fe_3O_4) and maghaemite (Fe_2O_3) are responsible for the permanent magnetism (Tite 1972). Magnetic contrast is a direct function of the amount of these oxides distributed in materials such as soils, structures and artifacts. The concentration of iron oxide in soil depends on its geological strata while structures and artifacts are manufactured with materials containing these oxides. In the case of clay and metal materials the thermal history can determine their magnetism by heating past a temperature termed the Curie Point. The **magnetic domains within the materials align with the magnetic field of the earth at this temperature producing an induced magnetism of greater strength than before firing. When the** object is moved at a later date, it retains this magnetic alignment and its enhanced magnetism. This capacity of field strength and direction retention forms the basis for magnetic dating techniques.

For the detection of magnetic anomalies in the Gulf of Mexico, amplitude will be directly related to the magnetic properties of the object or source, its alignment in the local magnetic field, and its distance from the sensor. Another factor which is related to the alignment is the direction of the earth's field. Because the earth behaves as a dipole magnet with magnetic lines of force, the direction of these lines of equal intensity or magnetic flux determine field strength. The field is strongest at the pales, weakest in the equatorial plane (Figure II-65). This directional aspect of magnetic fields ultimately means **that amplitude of an anomaly is a vectorial** sum of the earth's field and the weaker local field of the anomaly source:

$$\vec{T} = \vec{T_e} + \Delta \vec{T_e} + \Delta \vec{T_p}$$

(Eq. 3)

Where
T = the total field value
T_e = the earth or external field
ΔT_e = that part of the earth's field along **T_e**
ΔT_p · that portion perpendicular to T_e

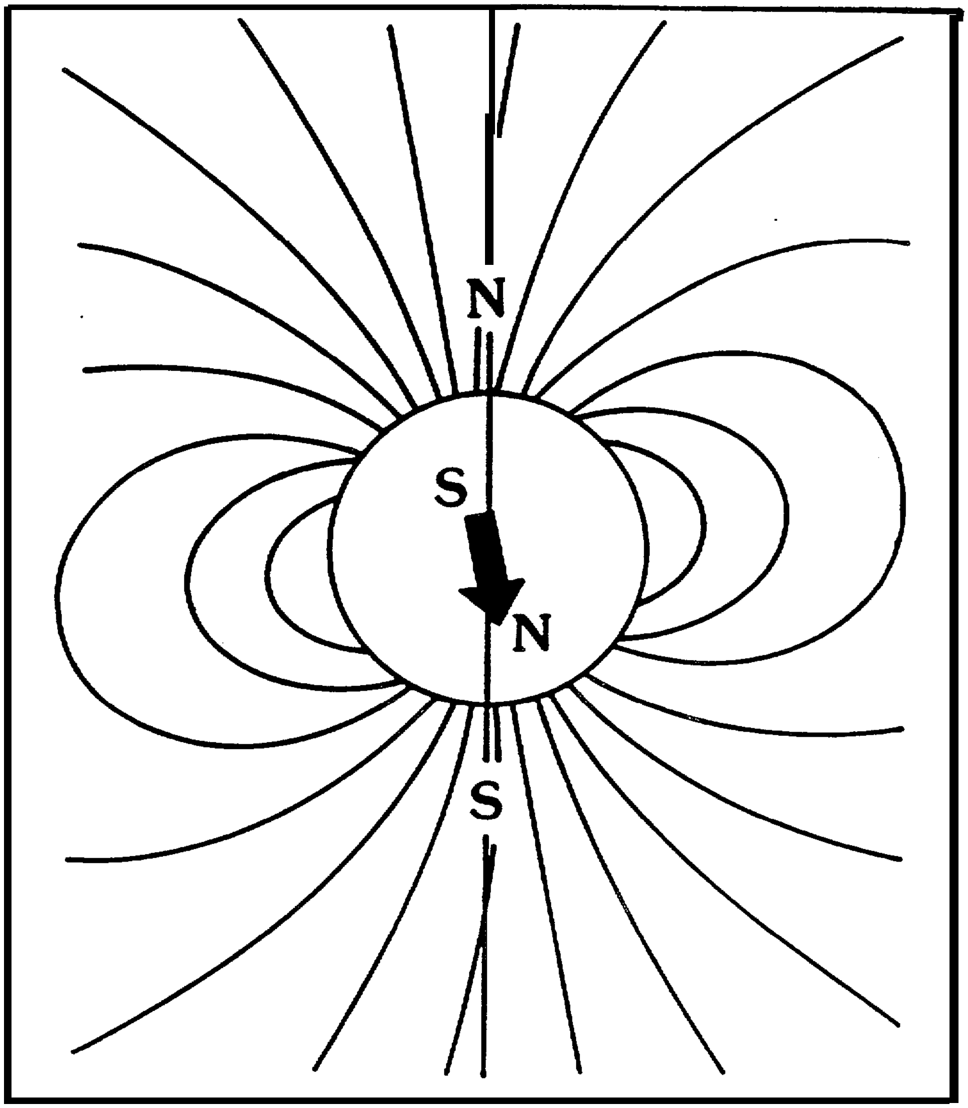


FIGURE II-65. Dipole field of Earth.

Because the sum of $T_e + \Delta T_e$ is roughly a million times or six orders of magnitude larger than T_p, the approximation becomes:

$$\vec{T} = \vec{T}_e + \Delta \vec{T}_e \qquad \text{(Eq. 4)}$$

The amplitude of the anomaly varies with the component T_e and its orientation relative to T_e. If it is parallel and in the same direction, it will simply result in Equation 2.

Any angular variation in T_e will reduce M by some constant k or,

$$\vec{T} = \frac{kM}{d^n} \qquad \text{(Eq. 5)}$$

A special case of this general equation is at the magnetic poles or above 60"N latitude where M becomes 2M. Orientation of the anomaly source within the earth's external field largely determines the observed amplitude. This accounts for the variation seen in Gulf lease survey data for reported anomalies. Typically, the anomaly is detected on one line of direction and detected again on an adjacent line of opposite direction. The anomaly amplitude will vary with d and T_e. Current survey methodology using opposite adjacent line directions make it difficult to assess the fall off factor, dn and thus, any estimate of anomaly size or distance particularly at the 150 m linespacing. Utilizing the 50 m survey methodology improved on this by having adjacent line directions at 100 m intervals. Groundtruthing surveys using 10 m offsets allowed for more rigorous application of evaluation techniques based on the formulae discussed in this section.

14.1 .1.3 Shape

The shape of a magnetic anomaly along a survey line is a result of the same factors that influence the amplitude. Most authors refer to shape as dipolar or monopolar. The fall off of the strength of the anomaly is expressed in the slope of the profile. Typically, the steeper slope values are associated with dipolar anomalies while monopolar anomalies have broader, less steep profiles (Figure II-66 a, b).

Ideally, anomalies in the Gulf of Mexico follow these rules (after Tite 1972):

a. The maximum of the anomaly lies to the south of the feature, the displacement being approximately equal to one-third of the depth to the center of the feature;
b. The separation between two points, in a straight line traverse, at which the anomaly has half its maximum value is approximately equal to the depth or width of the feature, whichever is greater (the full width-half max rule, FWHM); and
c. A reverse anomaly (i.e., decrease in magnetic field intensity) may occur to the north of the feature at a distance equal to the depth; the reverse anomaly does not exceed 10 percent of the maximum normal value of the anomaly except in the case of metallic iron.

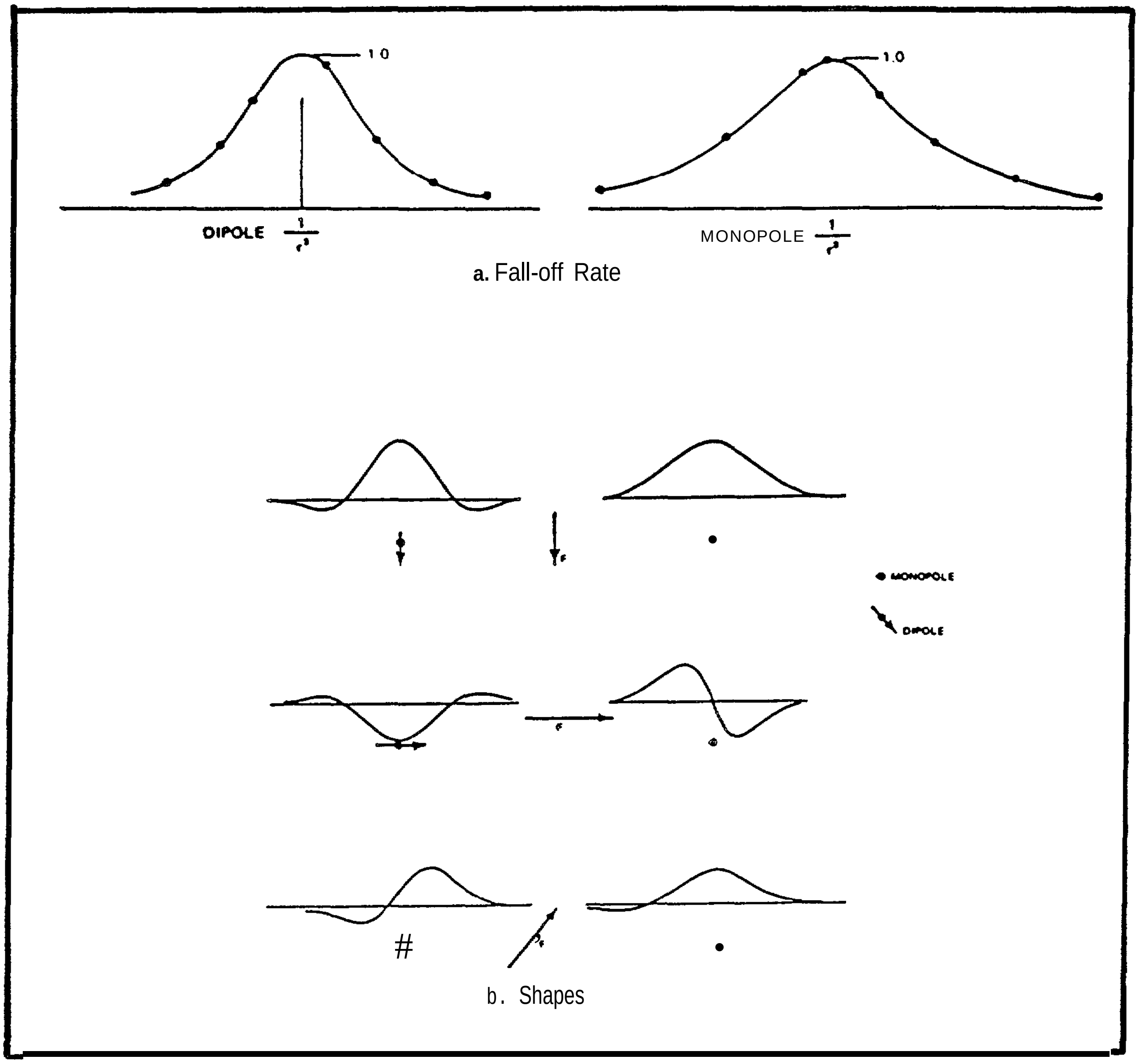


FIGURE II-66. **(a) Fall off rate for dipole and monopole**
(b) Anomaly shape relative **to field orientation.**

Breiner (1973) notes that anomalies are usually interpreted as though induced magnetization were the total source of the anomalous effects. Shape is therefore a combination of field and anomaly source orientation. This generally produces the asymmetry shown in Figure II-66 a, b.

Anomalies produced by shipwrecks or modern debris are variable in symmetry and reflect the kind of source materials. Von Frese (1978; 1984) suggested a technique termed "reduction to the pole" which aids in the recognition of remanent magnetized features. This technique moves the anomaly profile directly over its source and removes induced effects thus presenting the investigator with a profile representative of the nature of the feature. To date, this procedure has not been utilized on submerged anomalies and may be a tool for evaluating profile shape in a less qualitative manner than current methodology. Since almost all anomalies detected in the Gulf result from remnant magnetization in iron or steel materials, a technique which more accurately characterizes this parameter may prove analytically useful.

14.1.1.4 Sign

This parameter is related to shape, but is treated here as it applies to practices in lease survey reports. The reported values for anomaly amplitude are given in terms of the range or "peak-to-peak" values. Sign, in terms of an anomaly, is considered positive (+) when the observed amplitude exceeds the ambient external field, T_e, and is negative (-) when it falls below this value. It is a relative value dependent on the observed value for the external field.

Reporting the amplitude as a range ignores this property of anomaly behavior. One cannot correctly characterize the anomaly strength with a range value as it ignores the physical behavior of magnetic features. The magnitude of the reverse anomaly allows for a truer characterization of the anomaly as dipolar or not. However, using the reverse anomaly to calculate amplitude will not yield a value that agrees with a numerical result of a variation of Equation 1. The proper utilization of the amplitude of the anomaly and that of the reverse anomaly seems an important point to consider in the characterization of marine survey data.

14.1 .1.5 Frequency

The term used here is more commonly a synonym for the complexity of magnetic anomalies. Frequency relates to the parameter of noise from natural background variations. In marine surveys such background variation is usually the result of speed or fluctuation in sensor distance from the bottom. Local geology can introduce background noise as well,

Scollar (1 979) has observed that noise amplitudes can be the same order of magnitude as those associated with archaeological anomalies. Weymouth (1986) stresses the importance of distinguishing the nature and magnitude of noise separate from the signal if possible. In addition, he classifies noise by its frequency of occurrence. It can be random and non-repeatable or very regular. It can be long or short range occurring over several readings or just one or two. The importance of noise is that it sets a lower limit to the size of identifiable anomalies. In lease surveys the acceptable noise is three nanoteslas allowing for the detection of at least five nanotesla anomalies.

Noise can be removed by mathematical filtering techniques. Anomalies commonly have dimensions differing from that of noise and as such can be emphasized to the exclusion or reduction of noise. An approach called threshold median filtering or interquartile difference filtering removes noise by comparing values observed with a median value in a moving window (Scollar 1984). Where the value exceeds the interquartile difference, it is replaced by the median. A variation used in the analysis of the resurvey data is shown in Figure II-67. Here the noise has been filtered by using a moving comparison to a median and the frequency pattern observed for the long range noise (Kaplan and Coe 1976). The data displayed in Figure II-67 represents an entire three mile survey line. Such presentation introduces another parameter of magnetic survey data - trend or gradient. Trend analysis is a well established set of procedures that utilizes mathematics to remove trends (Davis 1970). In this analysis we have used what Davis terms convolution filtering. By using two-dimensional moving averages each data point is replaced by a weighted average of neighboring values inside a given radius.

Displays of this nature are possible when data is logged digitally and processed through algorithms that can image complete survey lines, line segments with anomalies shown, individually or together, as to frequency and complexity.

14.1.2 *Anomaly Characterization and Pattern Recognition of Resurvey and Groundtruthing Data*

The data used for the following analyses are those of the resurvey of blocks GA 313, GA 324, and GA 332. Various techniques of magnetic data display were used on various portions of this data base to characterize anomalies and recognize any patterns associated with these data. The groundtruthing data is appended to this report and cited in appropriate examples.

14.1 .2.1 Graphical Display of Resurvey Data - Single and Multiple Profile Techniques.

The first data were collected in GA 324. The analog magnetic data and digital navigation data were merged in the post plot process. This is the familiar technique utilized by leasees fulfilling survey requirements under NTL-75-3.

These data were plotted using DISSPLA graphics package which provided the perspective plot of magnetic anomaly profiles for GA 324 (Figure II-68). This method is **informative as** it allows for an easy assessment of the distribution of anomalies within the surveyed area. Individual detail for the anomalies can be obtained by relaxing the scale of the anomaly relative to the overall length of the survey line. Where anomalies are broadly dispersed, this linear scale exaggeration is convenient, In the case where anomalies are more clustered together or more dense overall, it may be less appropriate. Figure II-69 illustrates this point where a plot of **GA** 313 data is shown. The large anomaly of a well is seen but the scale has not been manipulated due to the density of adjacent anomalies. No detail of smaller anomalies can be seen at this scale.

Line profiles can be displayed individually for the further analysis of anomalies. The z-axis, which denotes amplitude, has been scaled such that low level noise is exaggerated. Smoothing produces an image like that for GA 324 {Figure II-68).

Figure II-70 for line 230 (GA 313) illustrates (a) raw data showing the gradient over the three mile survey line and (b) detrended, filtered data. The compression of the x-y scale **accentuates the z-axis (amplitude).** The well feature anomaly is clearly seen as in Figure II-69.

Multiline or adjacent line comparison is facilitated by the use of digitized data. In Figure II-71 (a), adjacent lines of GA 313 are shown where the same anomaly is seen on both lines near the right hand end of the tracks. Figure II-71 (b) illustrates this format using four lines adjacent to each other. No anomalies are seen in common.

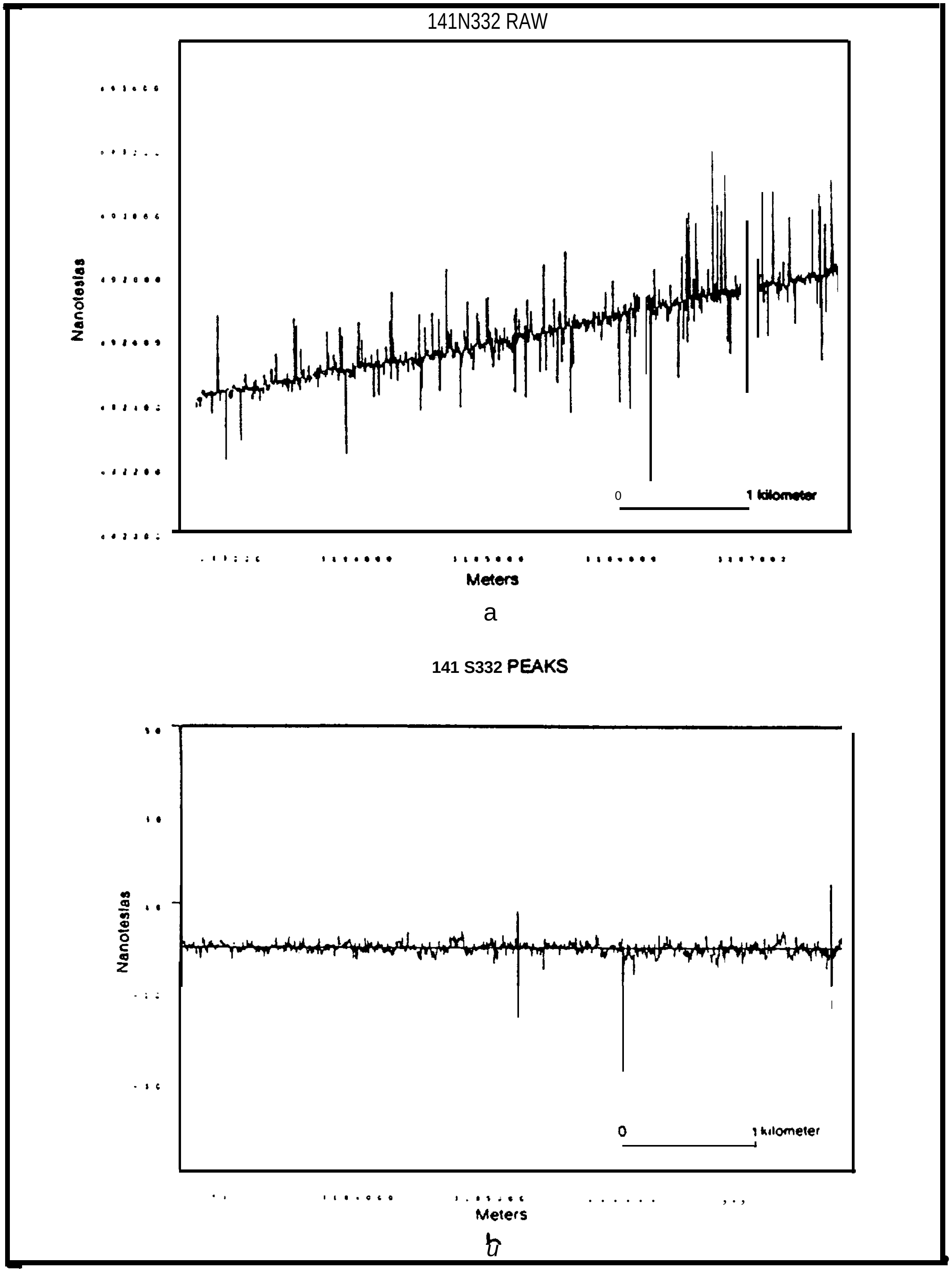


FIGURE II-67. **Noise filtering,** line 141 GA 332.

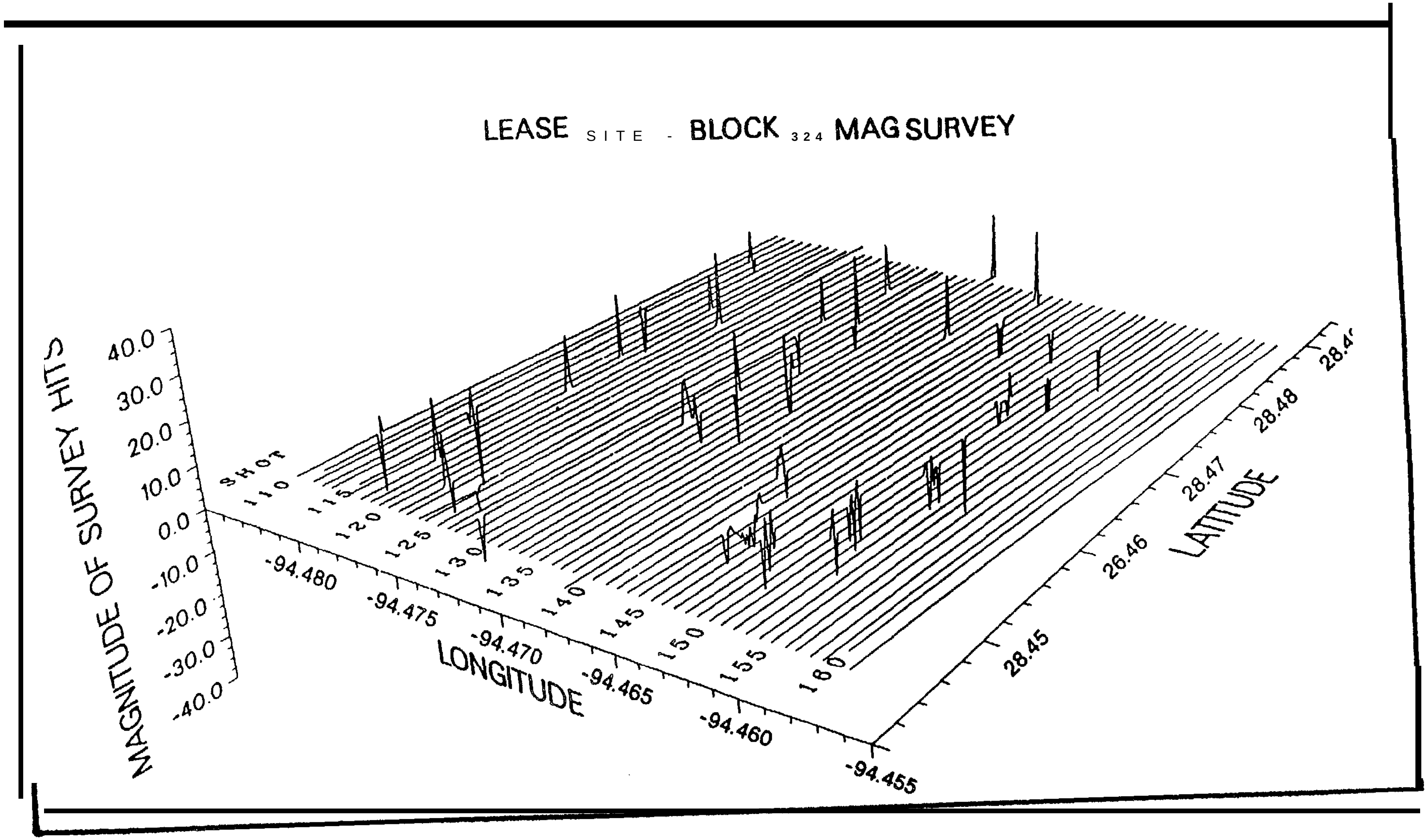


FIGURE II-68. Magnetic profiles, GA 324, DISSPLA graphics.

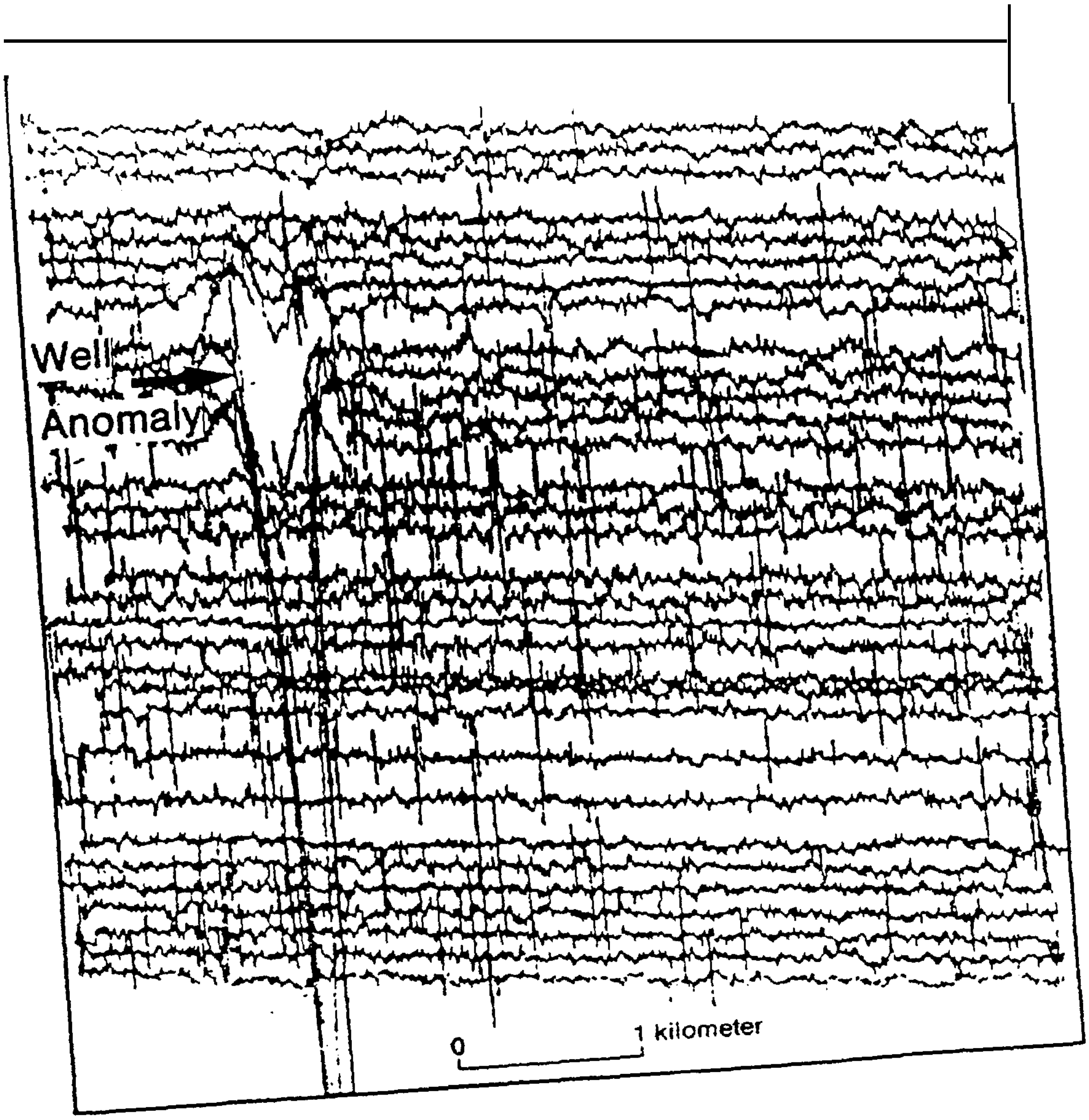


FIGURE II-69. Magnetic profiles, GA 313.

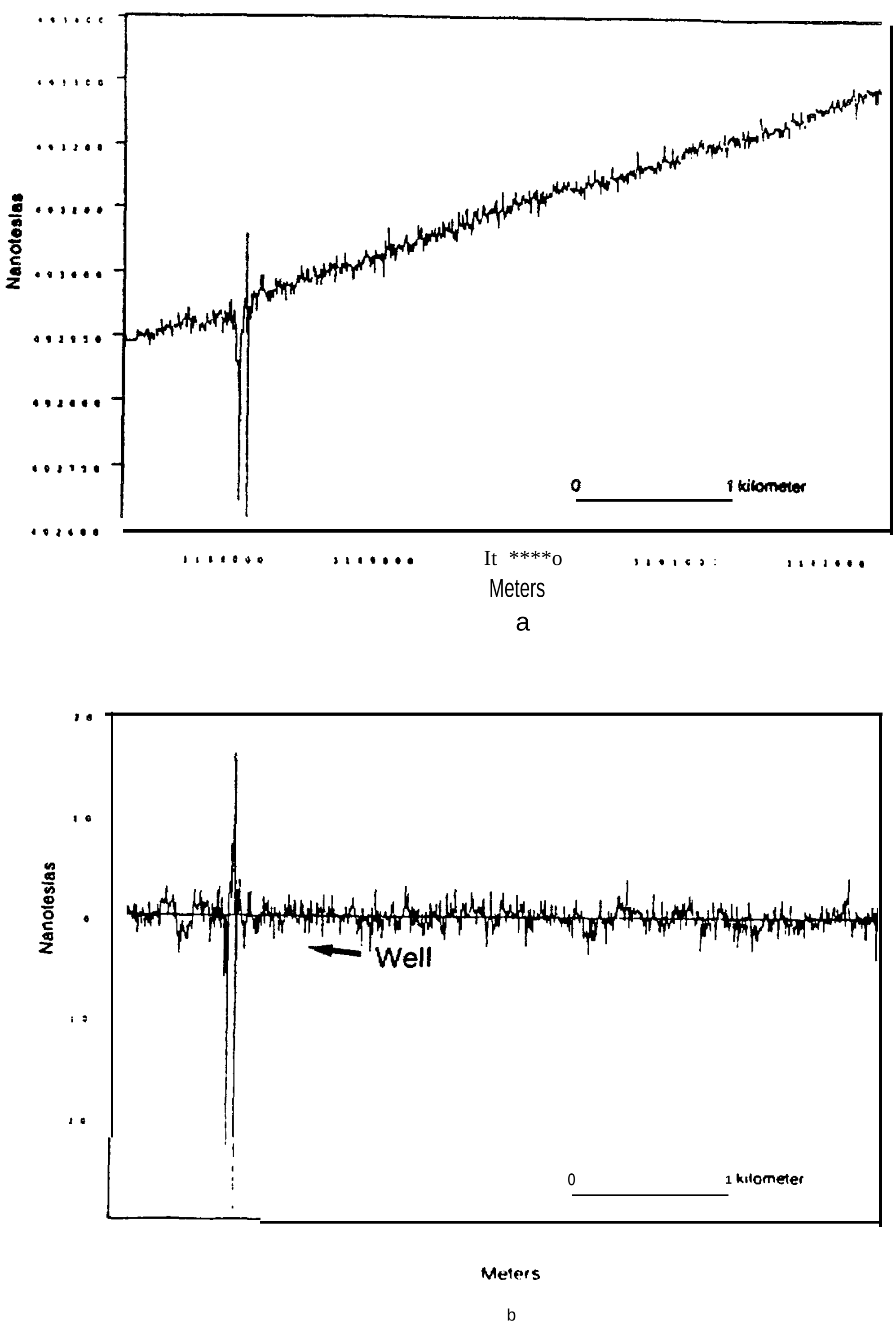


FIGURE II-70. Single *line* magnetic profile, (a) raw **data** (b) gradient removed, filtered.

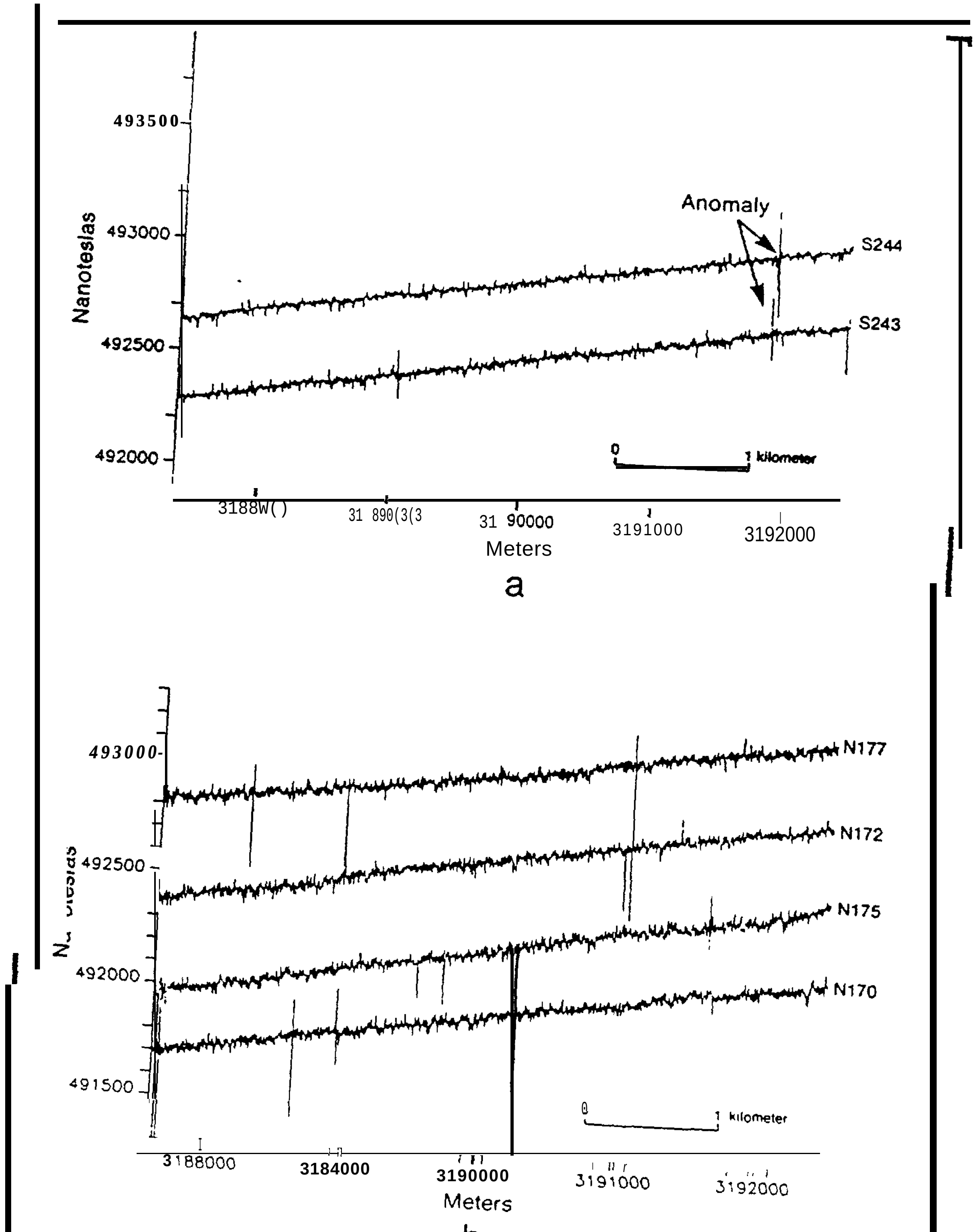


FIGURE II-71. Multi-profile display of data.

14.1 .2.2 Graphical Display of Resurvey Data - Contour and Isometric Formats.

Within many graphics packages, such as DISSPLA, are routines that create contour and isometric presentations of x-y-z data. The data base for GA 324 was utilized using DISSPLA. Similar results can' be obtained using DI 3000, a graphics package by Precision Visuals. Figure II-72 shows a contour map of the anomalies shown in the profile data of Figure II-68. As the data is sparse and contains no adjacent anomalies, the spatial extent is exaggerated and arbitrary. The visual presentation does allow the easy discrimination of monopolar and dipolar anomalies. The example of an isometric perspective of the same data (Figure II-73) is less informative as to the sign and amplitude of the anomalies. The distributional aspect is well depicted and if there were any anomalies with some complexity and/or spatial extent this format would be more useful. None of the above examples are called for under this study's scope of services and are presented as alternative methods in the graphical presentation of broad scale anomaly trends in lease blocks.

14,1.3 *Graphical Display and Analysis of Groundtruthing Data - Individual Anomalies*

The complete set of groundtruthing data is located in Appendix III-A. The suite presented in this analysis are those which have the most complete set of observations instrumentally as well as a reliable determination of their source. The aim is to examine and characterize the changes in magnetic signatures resulting from different sources, source orientations, and distances. Side-scan sonar **data,** where available, help establish a characterization of the anomalies or anomaly patterns,

14.1.4 Individual Sites

14.1 .4.1 Site 2, Line 107 GA 332-SP106

The sharp gradient magnetic anomaly detected during resurvey (Appendix K, Figure K-2a) was not replicated during groundtruthing relocation. A dipolar anomaly (Appendix K, Figure K-2b) was found during these efforts with an adjacent anomaly 10 m away. Divers obtained localized readings on the metal detector but were unable to physically locate the source due to burial in the mud.

Figure II-74 shows a 2 nT contour plot of the anomaly and an isometric view (Figure II-7; Figure II-87). In this latter case, the source was verified, by groundtruthing, as a cable. The source of this anomaly is thought to be the same.

14.1 .4.2 Site 7, Line 125 GA 332-SP156

This anomaly is a cluster of small anomalies scattered over a 50-75 m diameter area. The anomalies are small with largest being 27 nanotaslas (Appendix K, Figure 7b). The anomalies were of short duration (5 see) rarely over 12 m.

The contour and isometric views (Figures II-76 and II-77) enhance the discrimination of the spatial amplitude of this scatter of sources. Groundtruthing provided no identification of the anomalies due to burial depth.

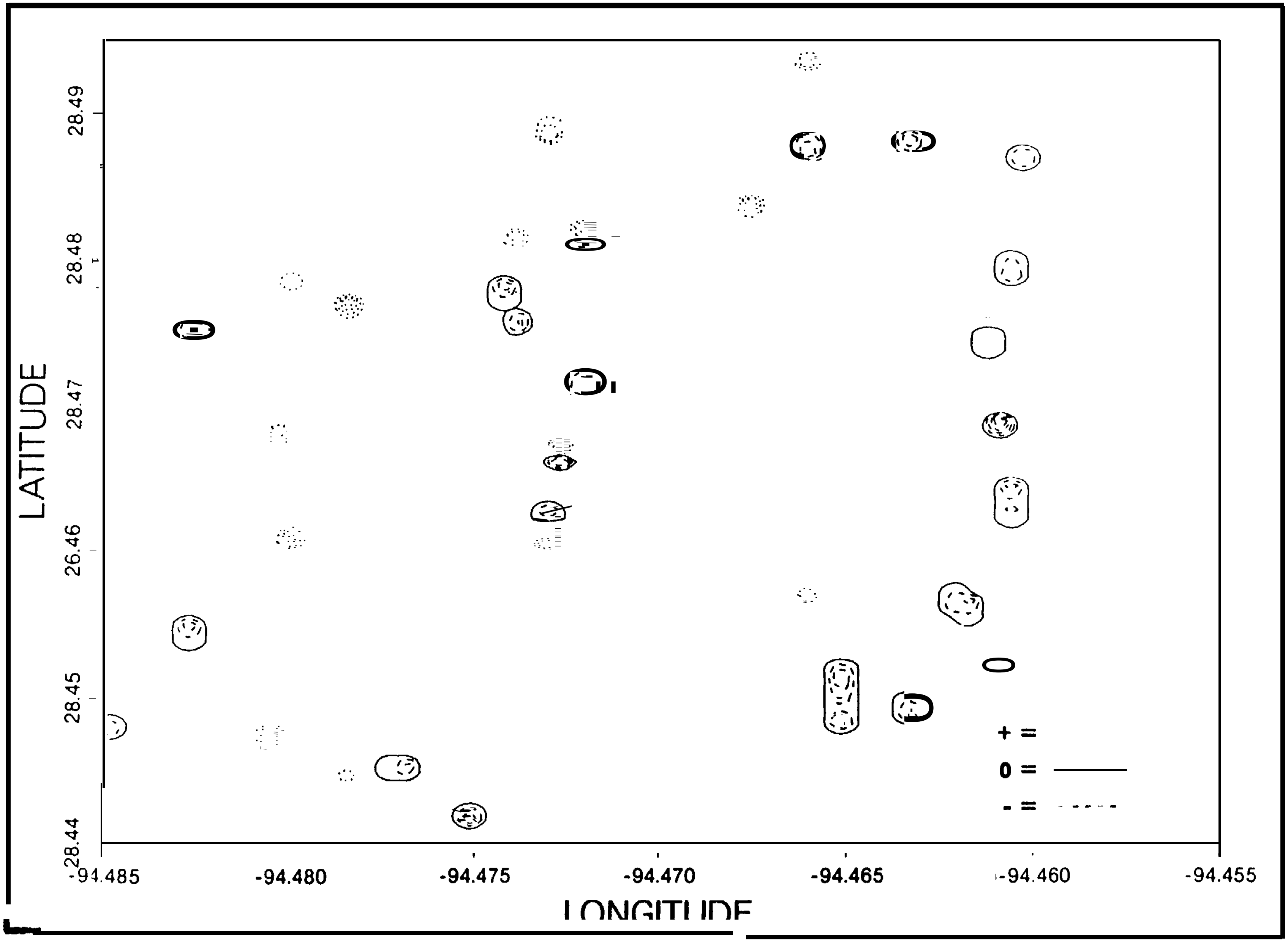


FIGURE II-72. Magnetic contour map, GA 324.

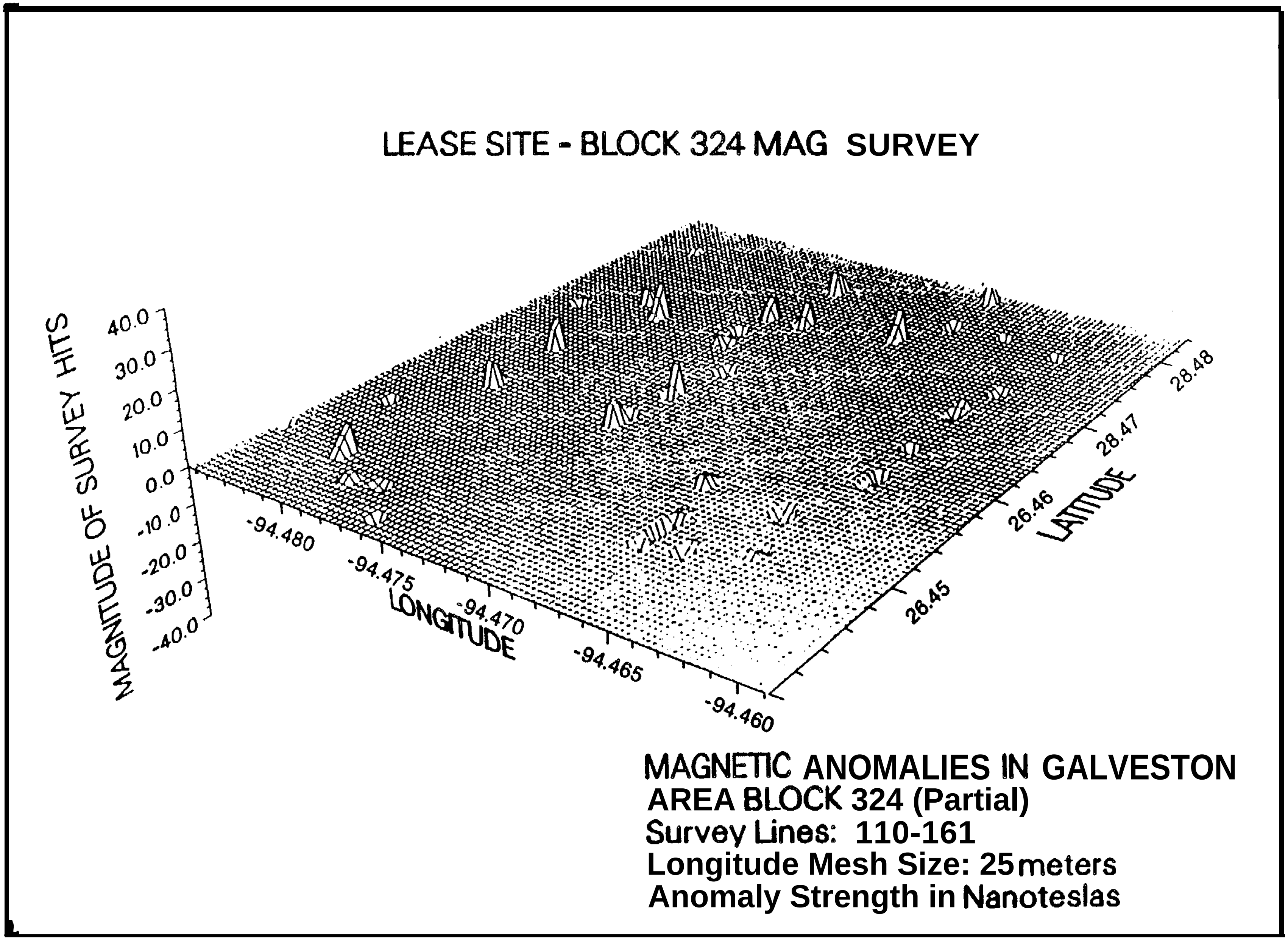


FIGURE II-73. Isometric view of magnetic data, GA 324.

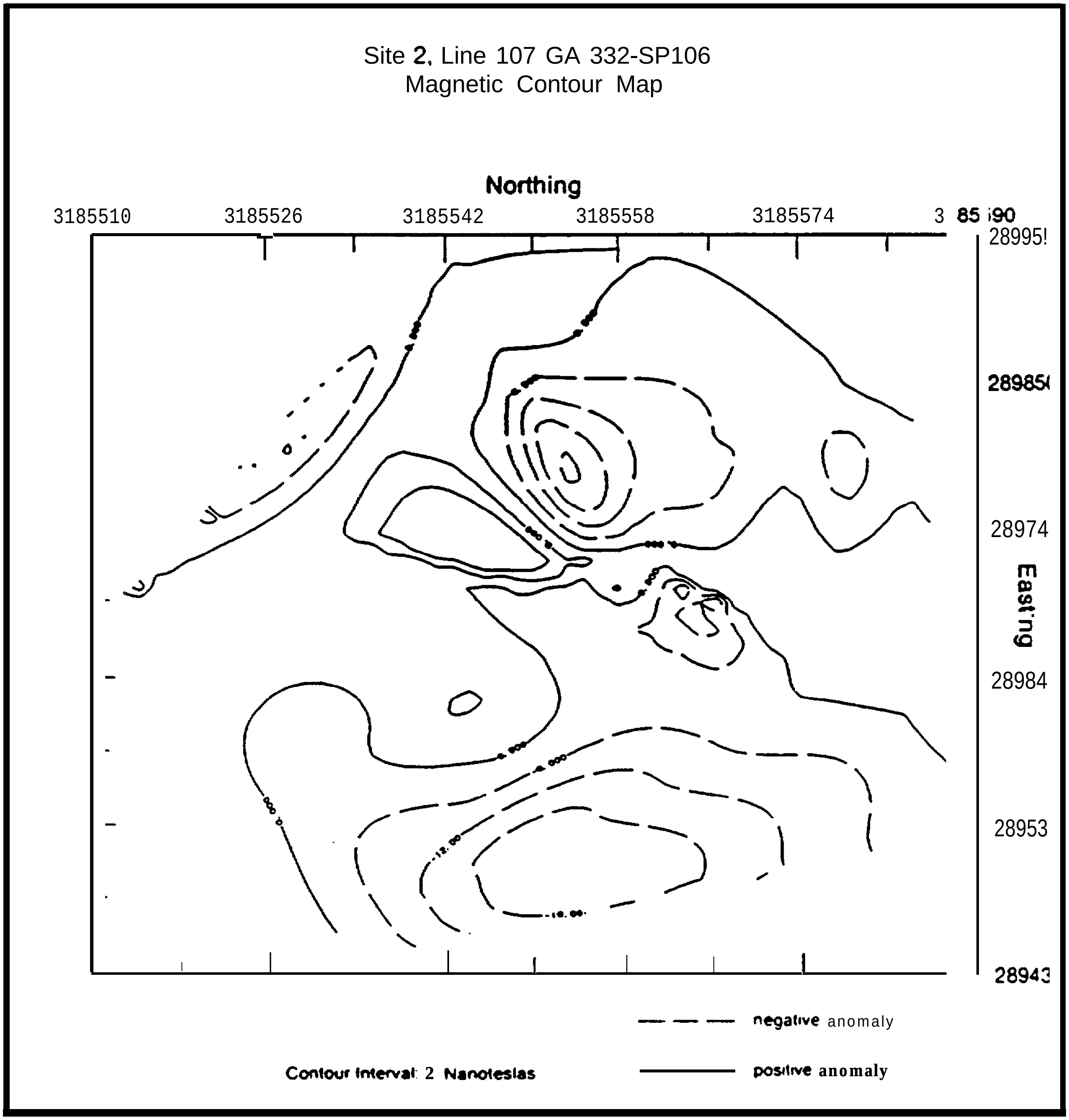
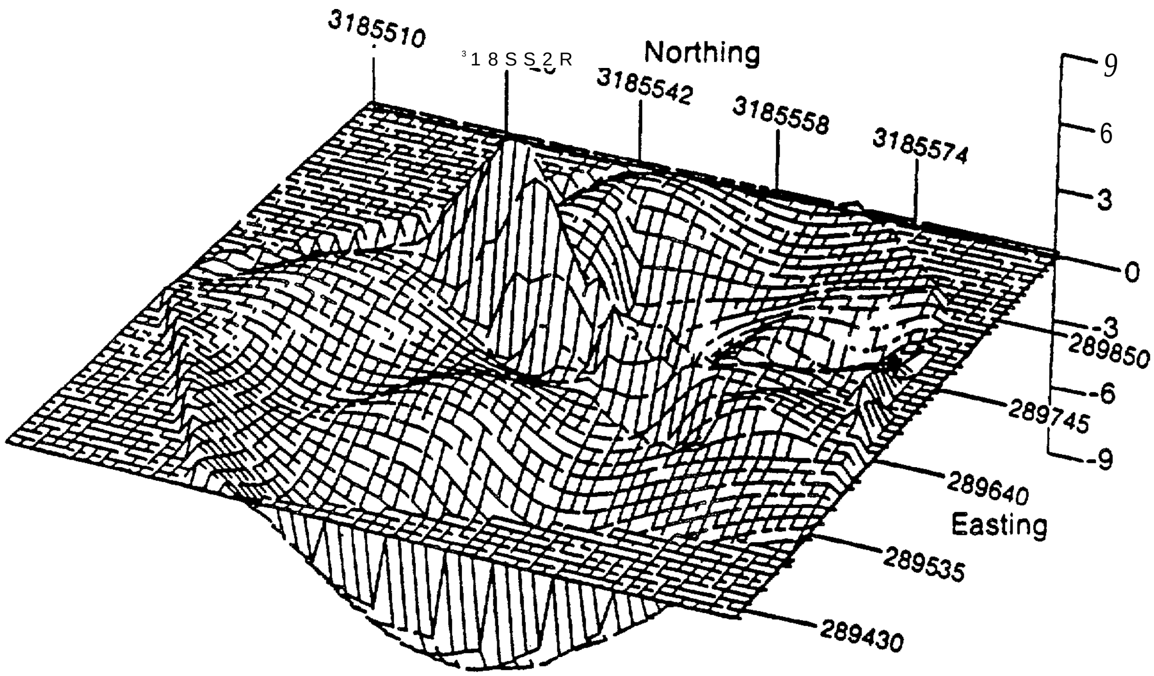


FIGURE II-74. Contour plot of site 2, 207 GA 332.

Site 2, Line 107 GA 332-SP106
Three-dimensional Magnetic Map



UTM Coordinates (meters)

Anomaly Strength in Nanoteslas

FIGURE II-75 Three dimensional plot of site 2, 107 GA 332.

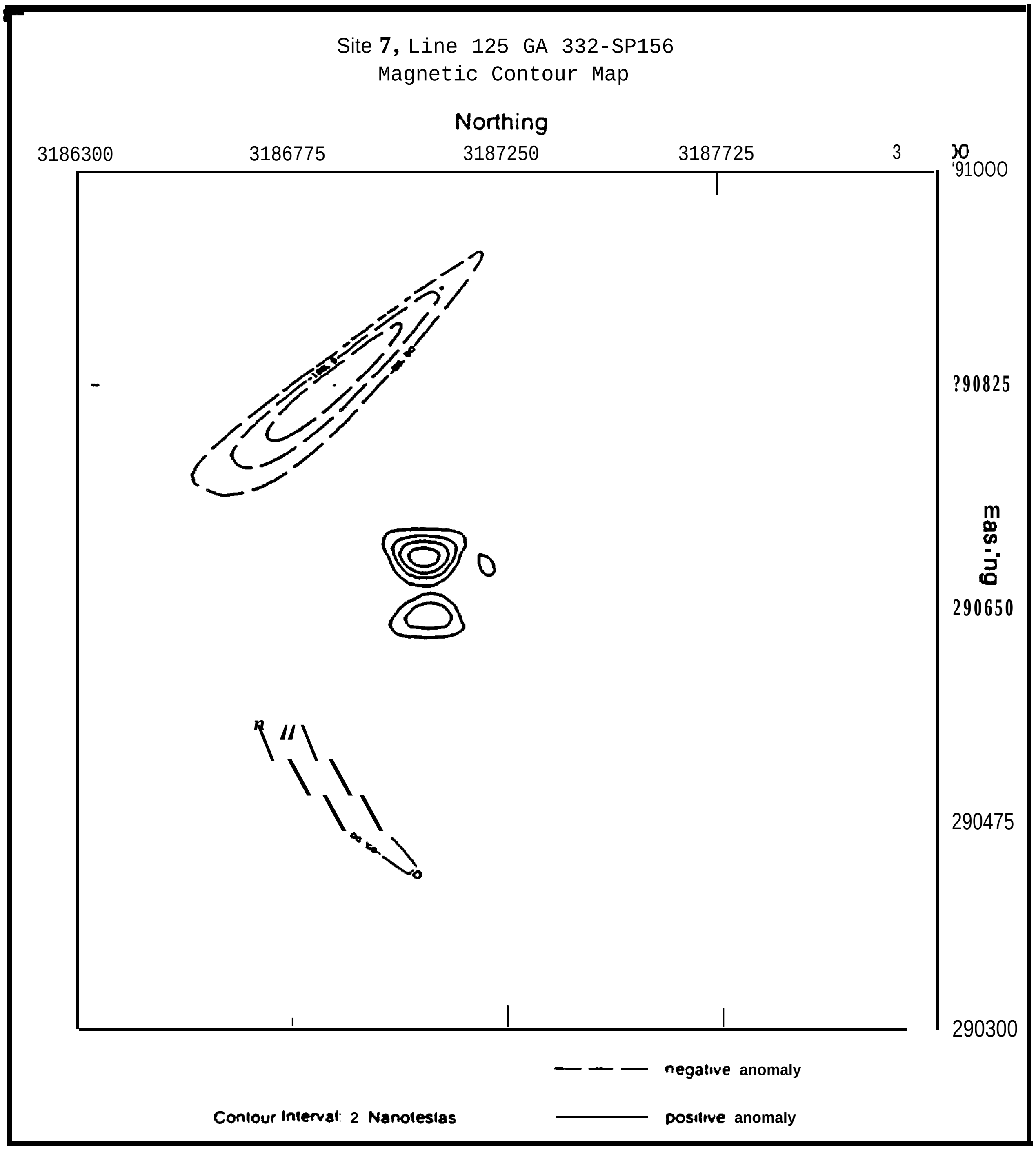


FIGURE II-76. Contour plot of site 7, 125 GA 332.

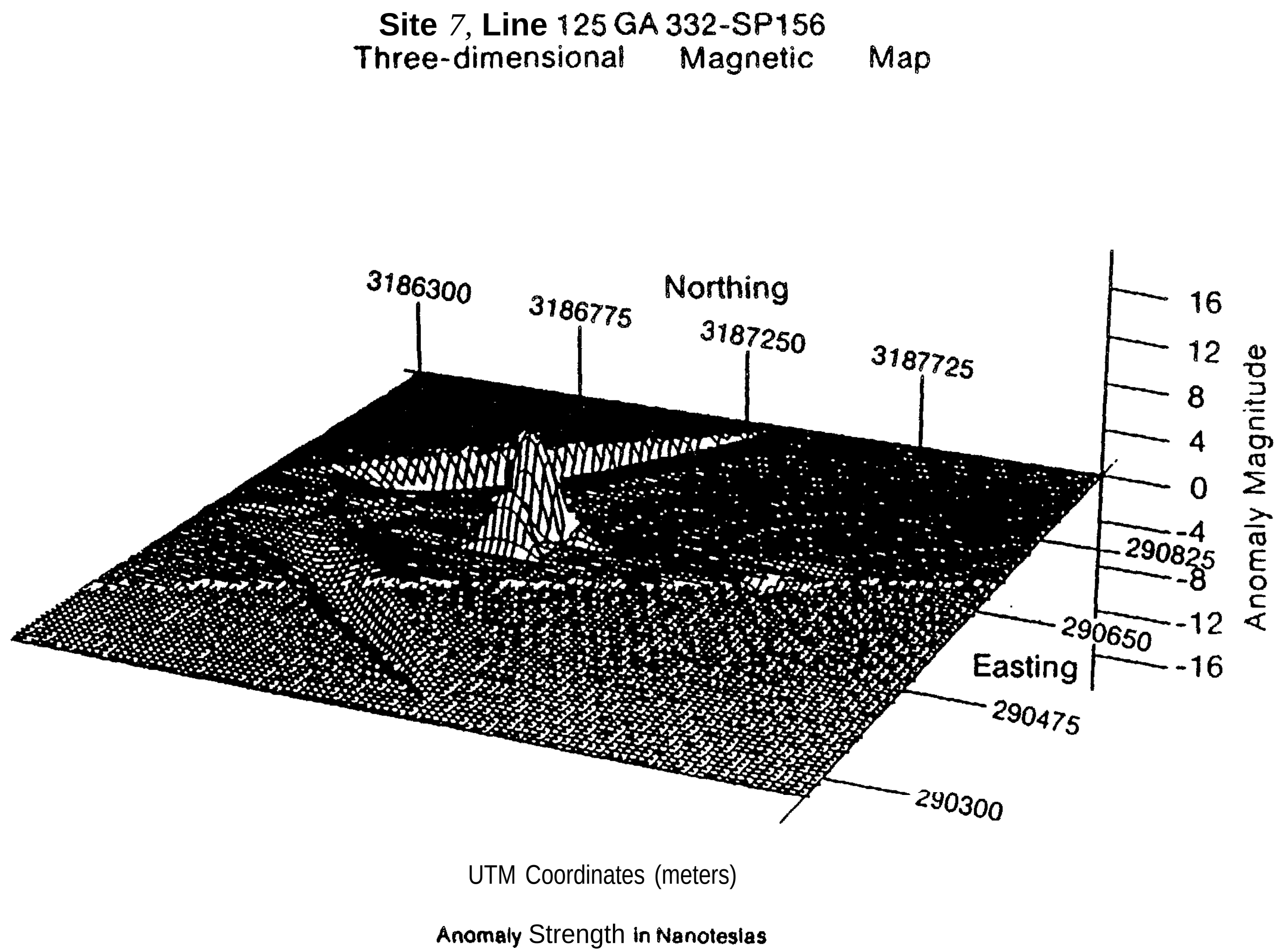


FIGURE II-77. Three dimensional plot of site 7, 125 GA 332.

14.1.4.3 Site 8, Line 137 GA 332-SP144

The anomaly found during resurvey was relocated during **groundtruthing** as a moderate magnetic feature (Appendix K, Figures 8b, and 8c). The small spatial extent and duration (2-3 m) together with a lack of complexity is shown in Figures II-78 and II-79. No dives were made on this site and it was classified as marine debris in an anchorage area.

14,1 .4.4 Site 9, Line 148 GA 332-SPI 06

The 94 **nT** anomaly found on resurvey was more clearly defined upon **groundtruthing** relocation activities. The duration was significant, approaching 34 m (13.5 see). The amplitude could not be duplicated, with 13 **nT** the maximum value recorded during relocation (Appendix K, Figure **K-9b).**

Our contour and isometric displays show a broad, localized anomaly centered over a buried source (Figure 11-80 and II-81). **Groundtruth** dives were planned but could not be carried out due to poor weather on **the** last day of the field work. The signature resembles that of **remnantly** magnetic cable or chain. The anomaly shows no distinct orientation affects which would be associated with a liner source such as pipe.

14.1 .4.5 Site 11, Line 152 GA 313-SP114

This feature was originally classified as a side-scan sonar target without any associated magnetic anomaly (Figure II-82 and II-83). Upon relocation during **groundtruthing** activities, a low amplitude anomaly was detected.

Divers located the scar marks of a large jack up drilling rig. These depressions were up to 1.5 **m in depth (Appendix K, Figures** K-11a and K-11 b). Metal detector survey of two depressions proved negative.

14.1 .4.6 Site 12, Line 164 GA 313-SP162

This side-scan sonar target (Appendix K) had no large magnetic features. The anomaly shown (Figures II-84 and II-85) is not believed to be associated with the long anchor drag scar. This identification is made based on the characteristics of the sonar image notably the chain pattern at the end of the drag. Divers confirmed the identification of the feature during an easy relocation.

14.1 .4.7 Site 13, Line 175 GA **313-SP126**

This broad anomaly (6 see, 15 m) has a **monopolar** character when detected on a single line (Appendix K, Figure K-13a). This is true for adjacent lines with the sign of the anomaly changing with line direction (Appendix K, Figure K-13b, c). Maximum amplitude is 29 nT(Appendix K, Figure K-13b).

Graphical display of the relocation magnetic data shows a different spatial character to the anomaly. In the data we see three separate **monopoles** (Figures II-86 and II-87). These are shown in other perspectives such as the contour and isometric grid displays. **Groundtruthing** by divers located a cable whose spatial extent clearly shows why the magnetic pattern is as it is, e.g., a large loop that individual lines represent a single **monopolar** anomalies.

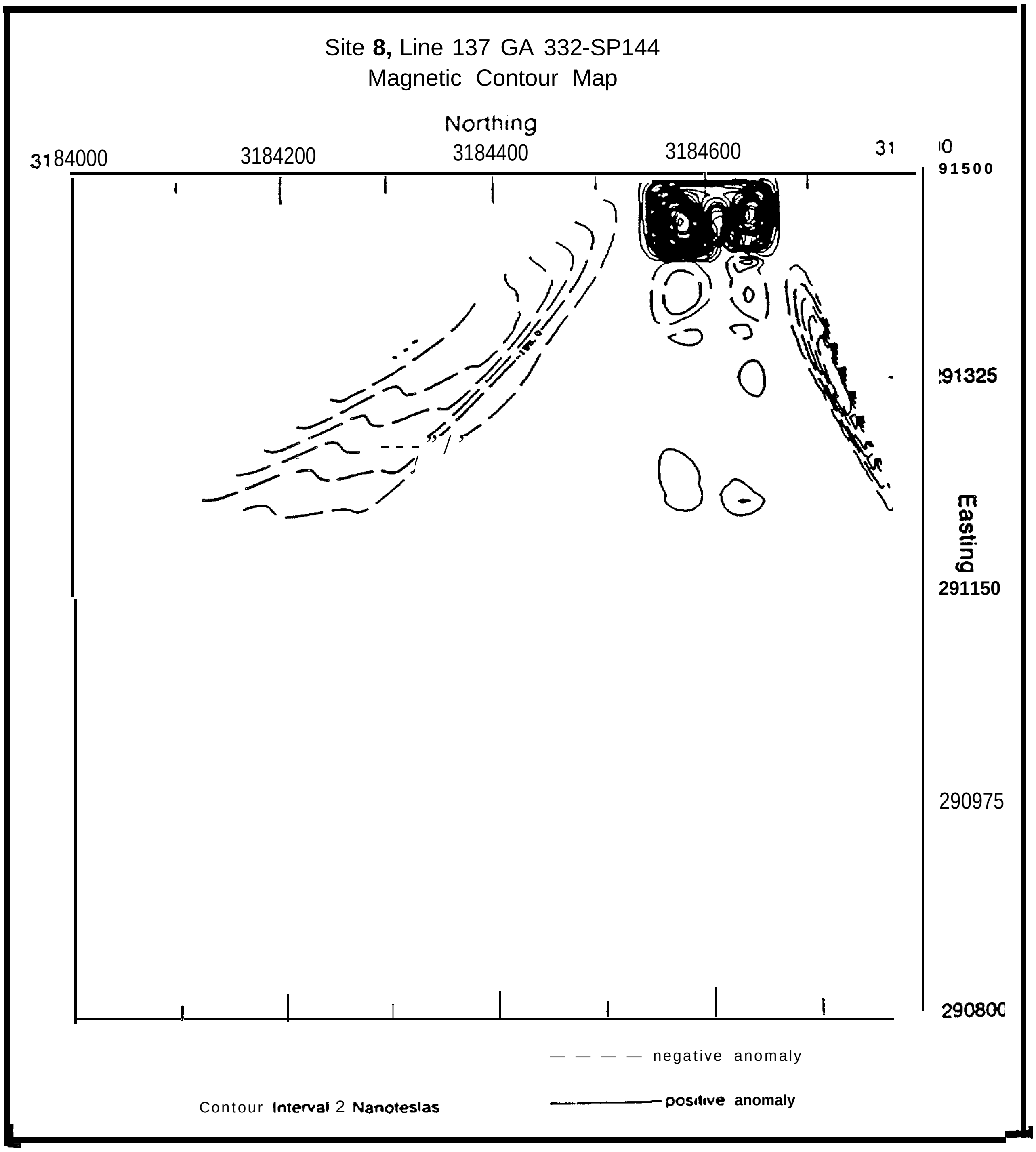


FIGURE II-78. Contour plot of site 8, 137 GA 332.

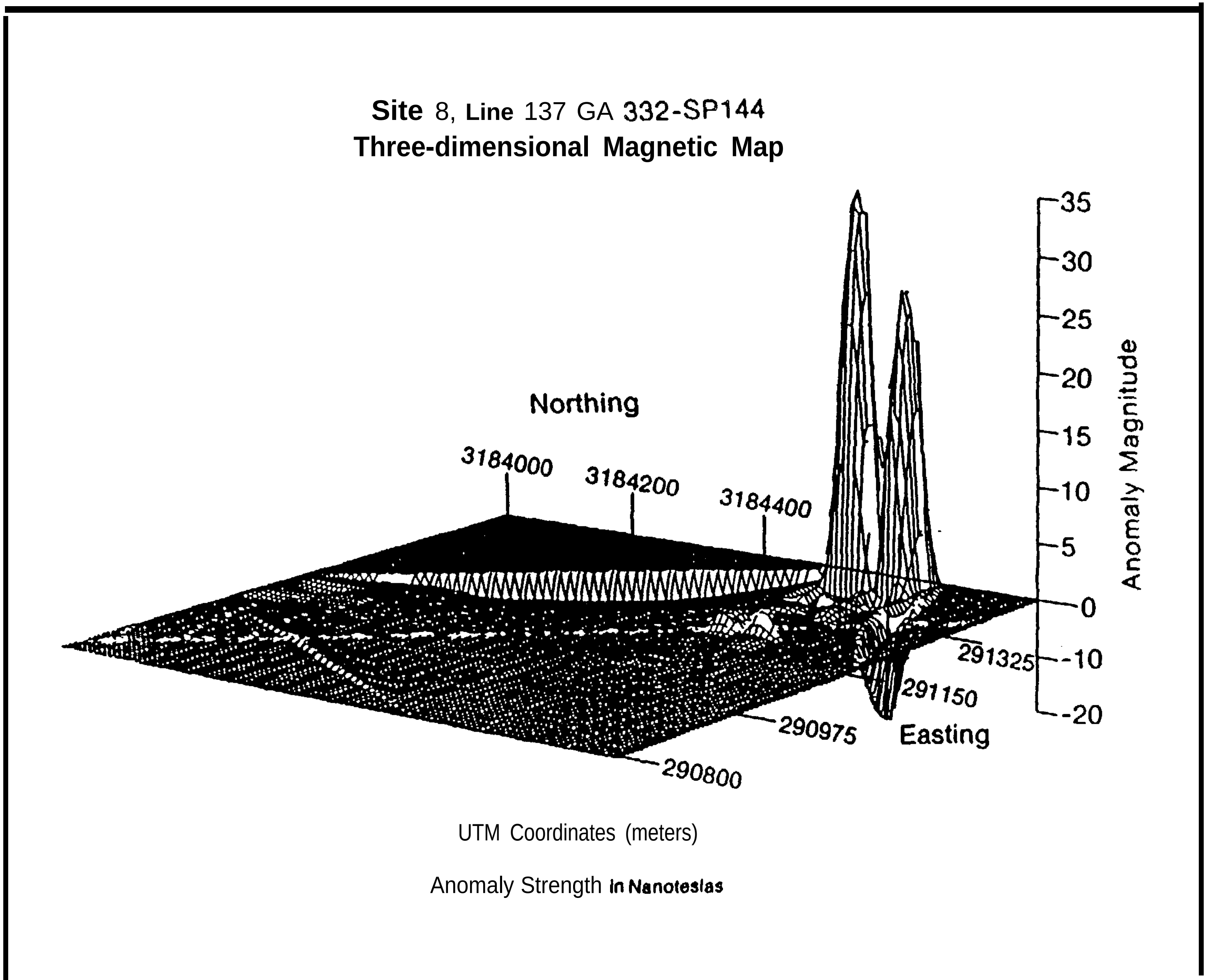


FIGURE II-79. Three dimensional plot of site 8, 148 GA 332.

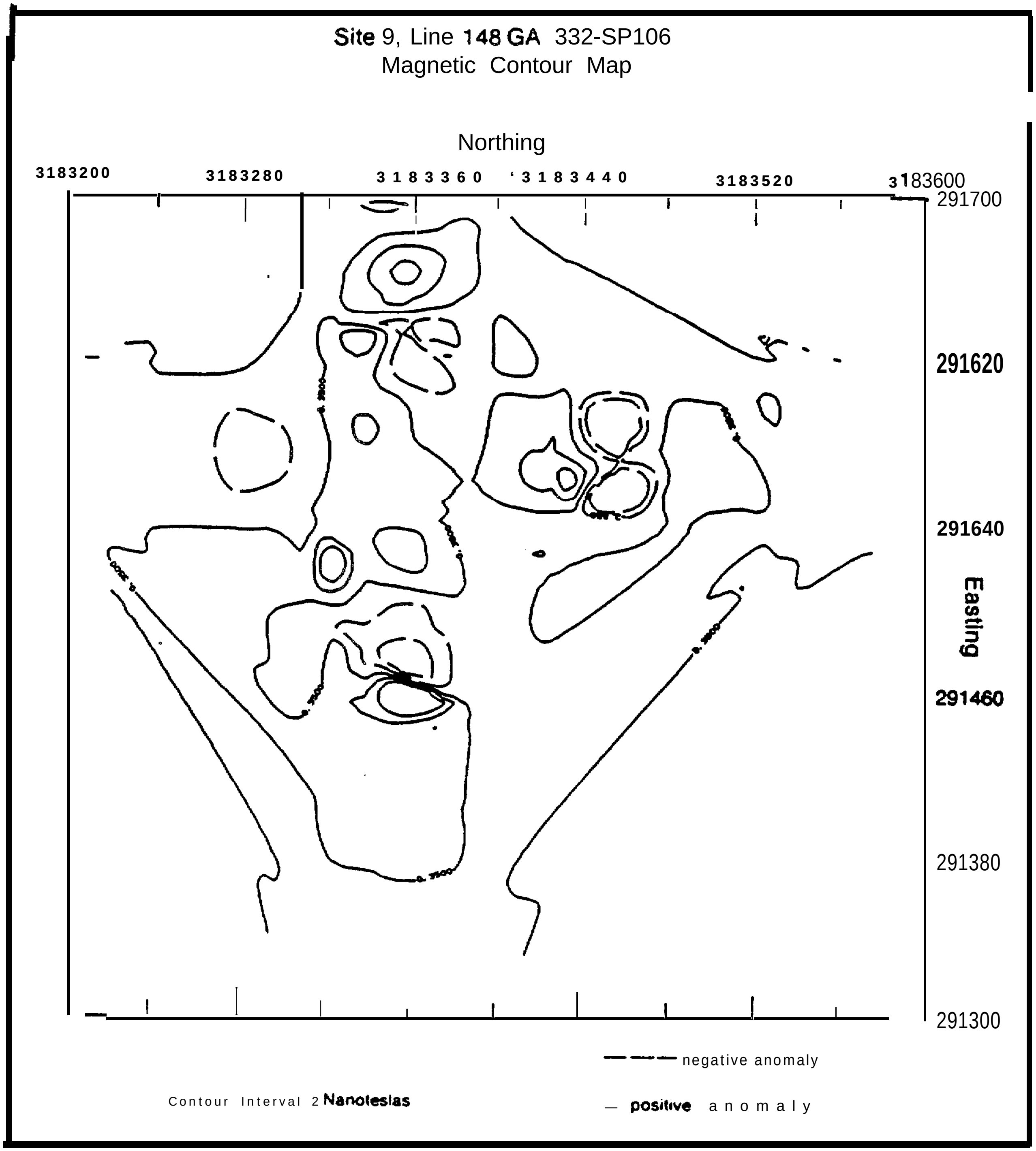
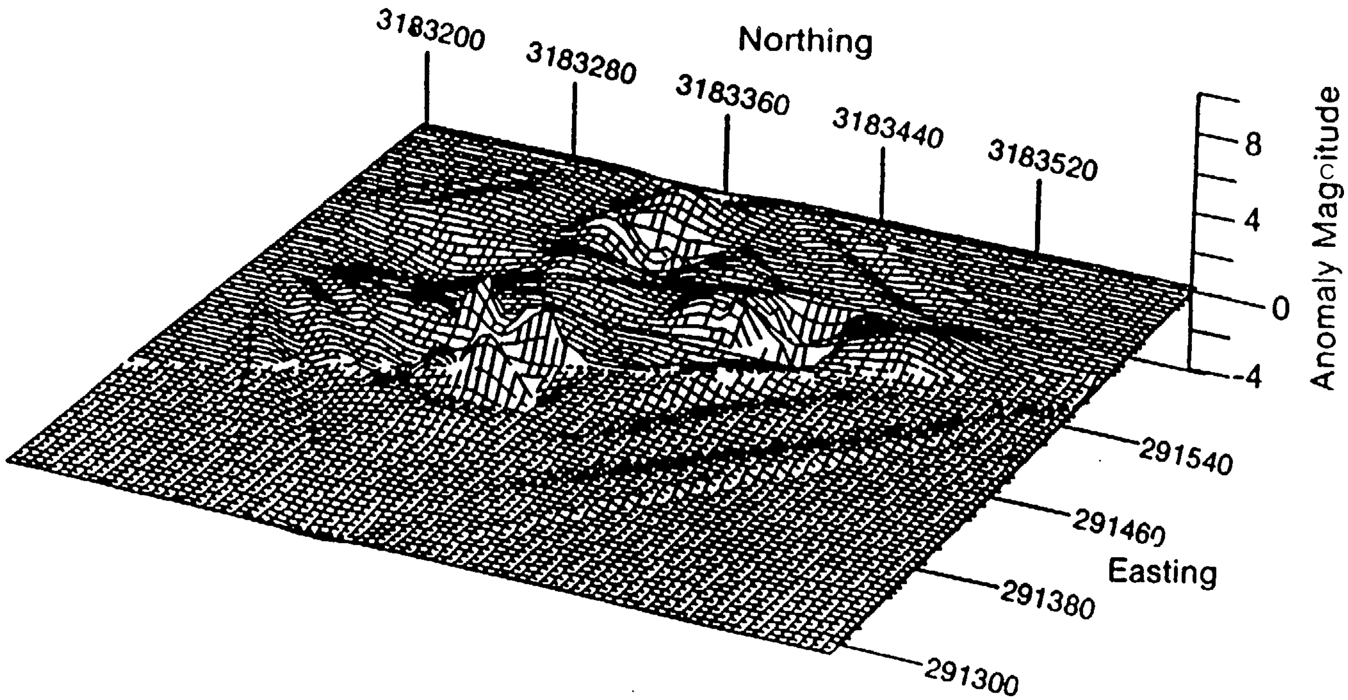


FIGURE II-80. Contour plot of site 9, 148 GA 332.

Site 9, Line 148 GA 332-SPI06

Three-dimensional Magnetic Map



UTM Coordinates (meters)

Anomaly Strength in Nanoteslas

FIGURE II-81. **Three dimensional plot of site 9, 148 GA 332.**

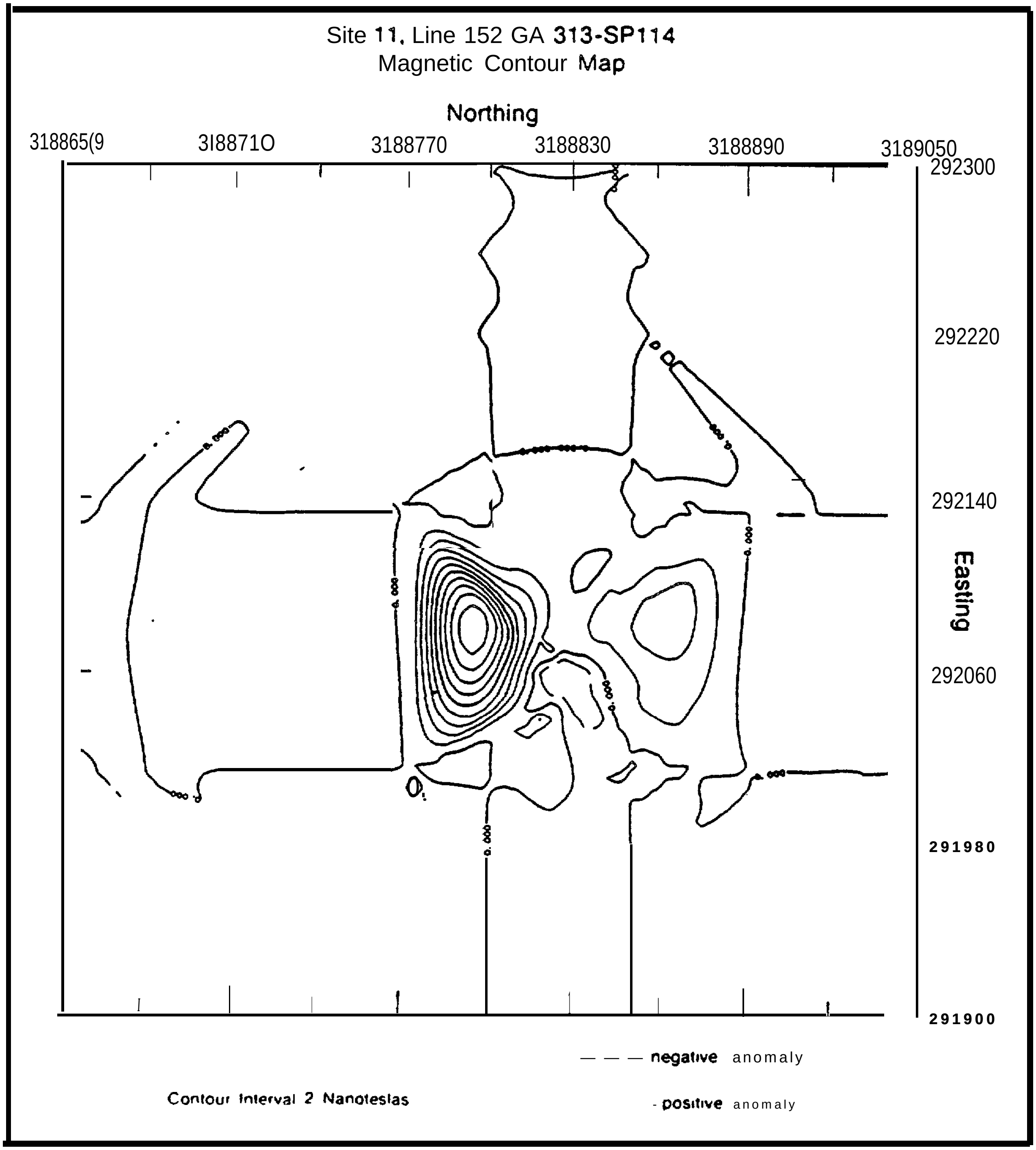
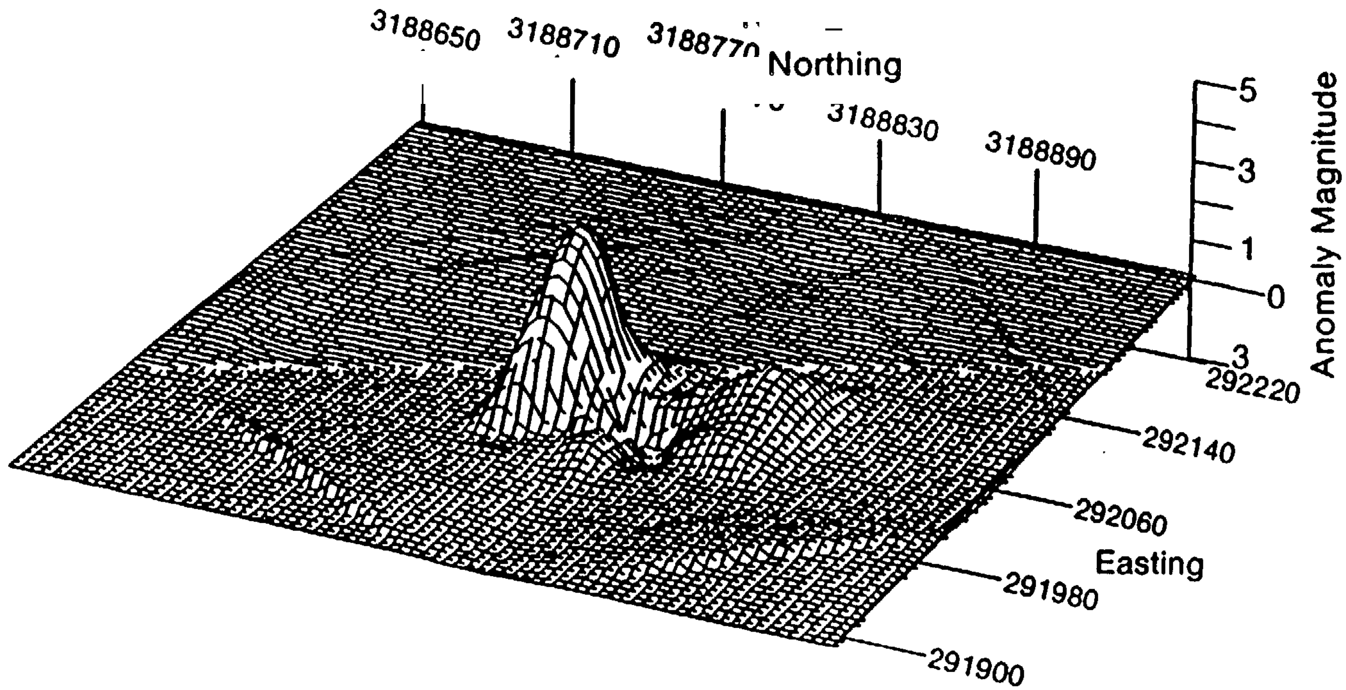


FIGURE II-82. Contour plot of site 11, 152 **GA 313.**

Site 11, **Line 152 GA** 313-SP114
Three-dimensional Magnetic Map



UTM **Coordinates** (meters)

Anomaly Strength In **Nanoteslas**

FIGURE **II-83.** Three dimensional plot of site 11, 152 GA 313.

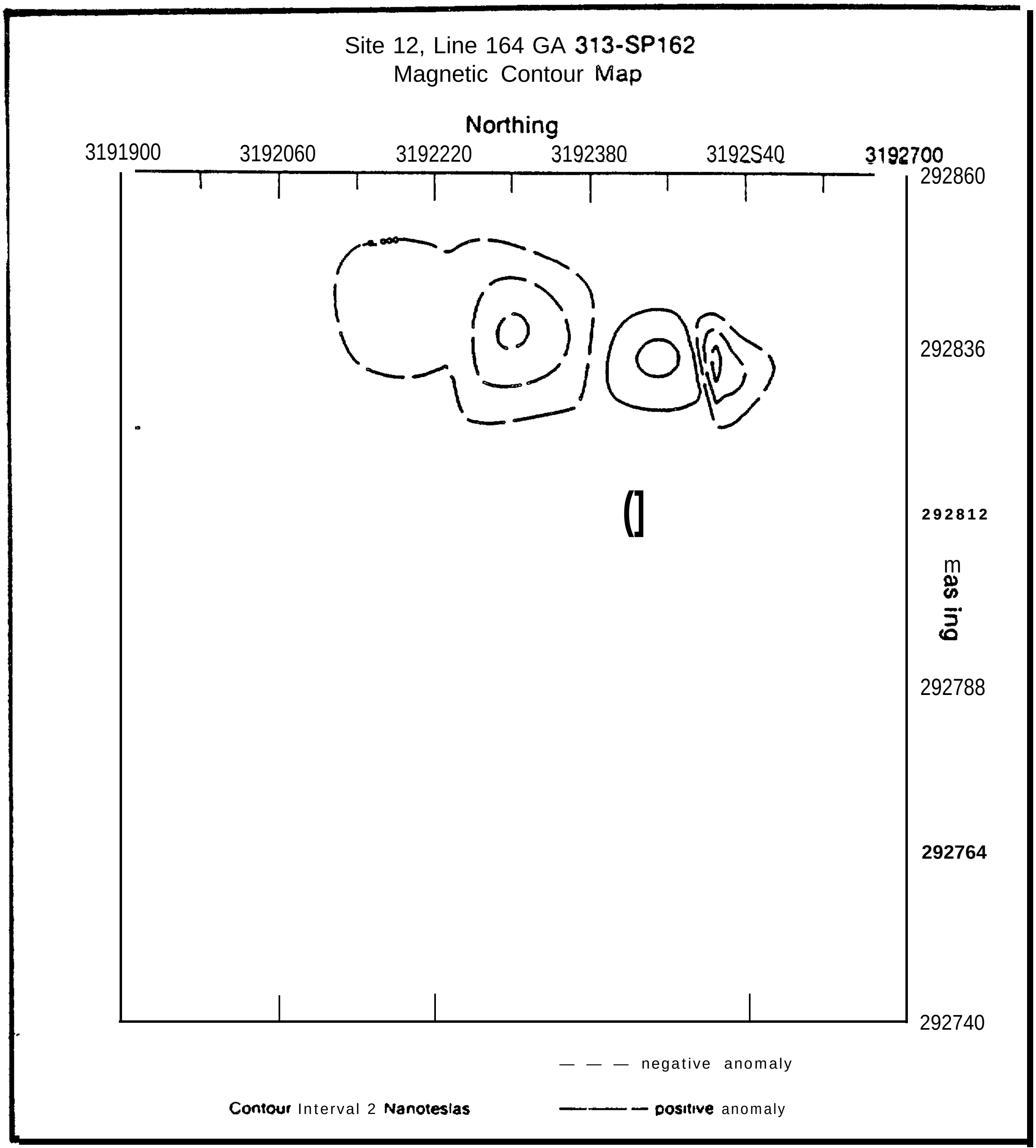


FIGURE 11-84. Contour Plot of site 12, 164 GA 313.

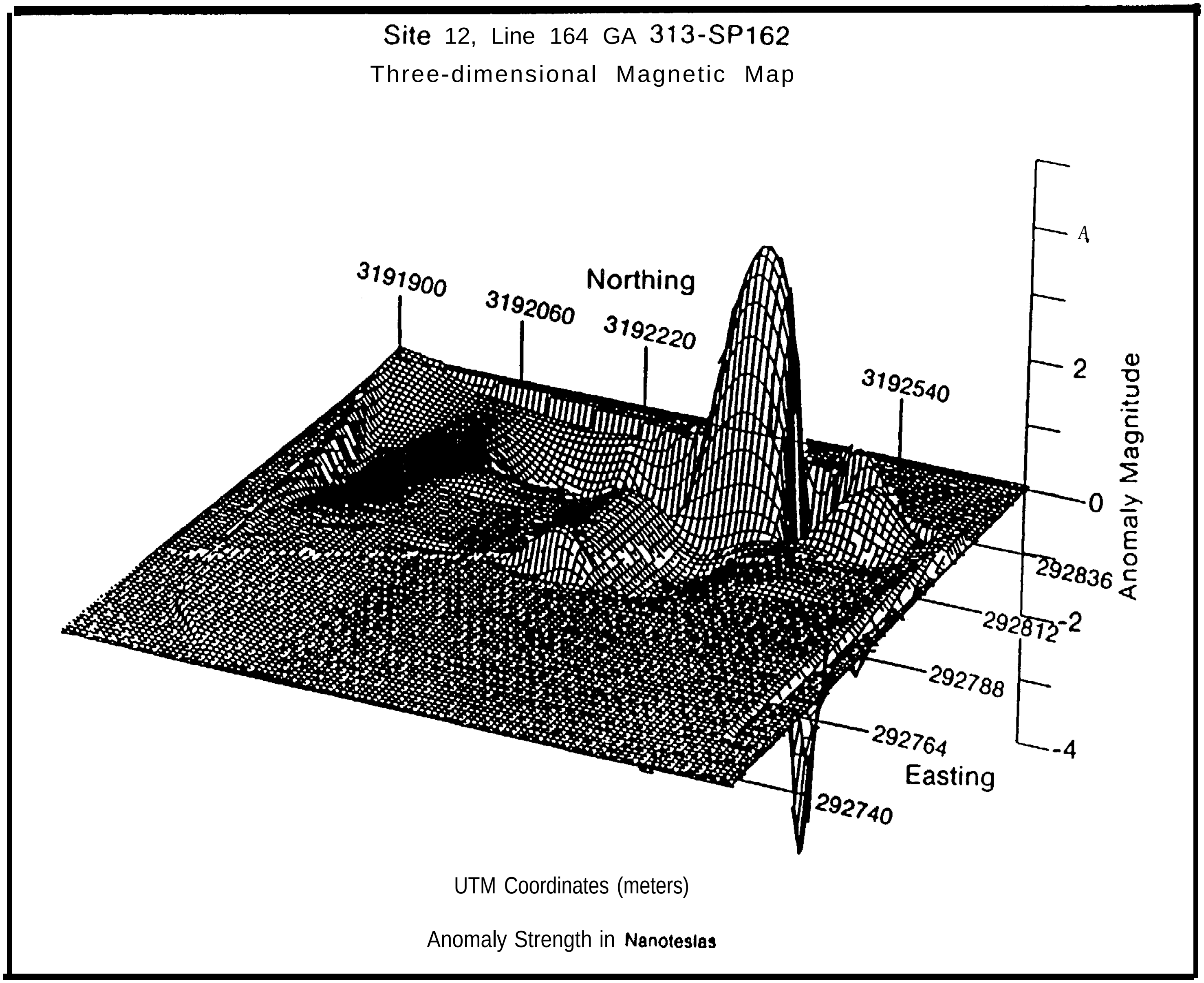


FIGURE II-85. Three dimensional plot of site 12, 164 GA 313.

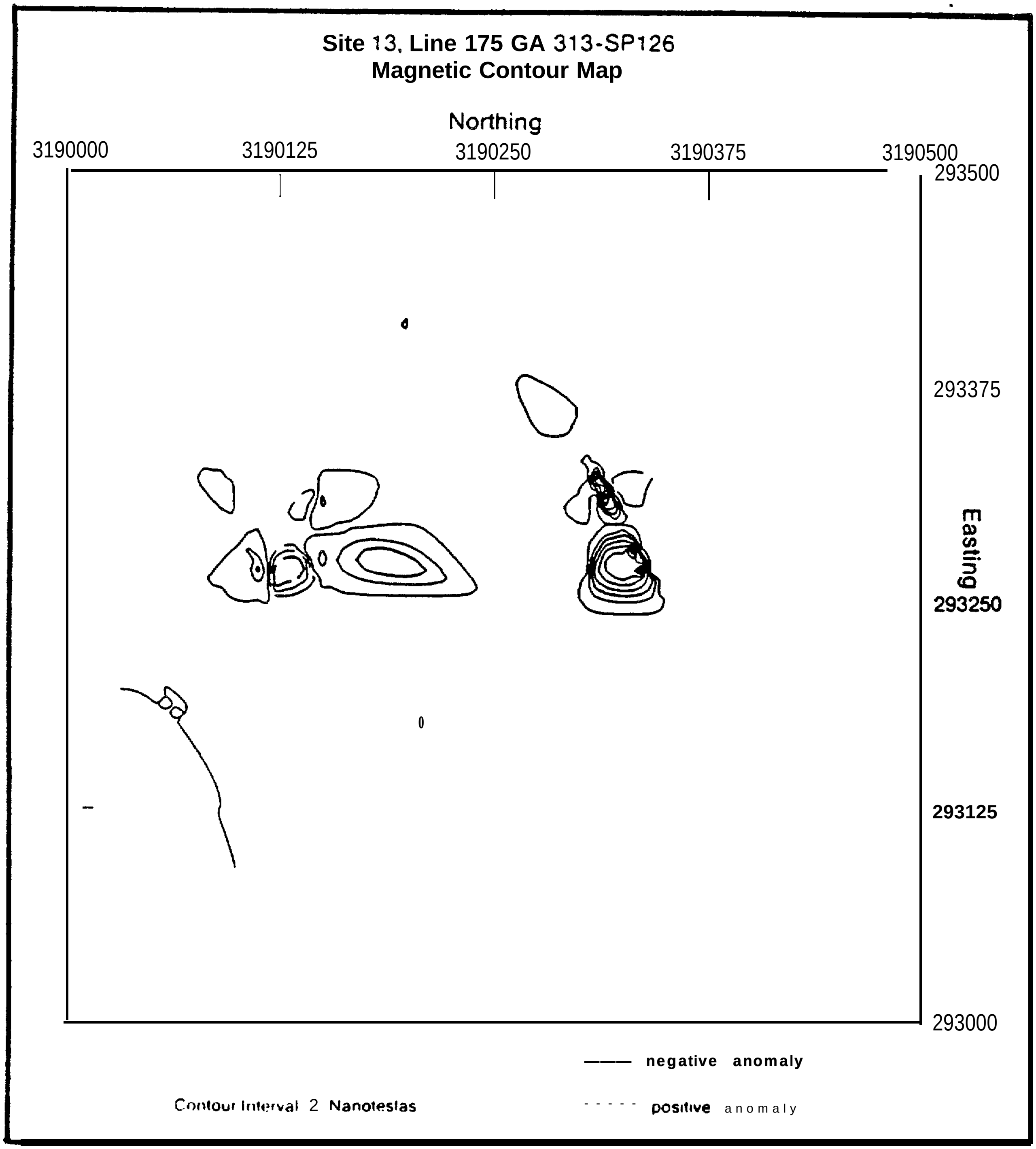
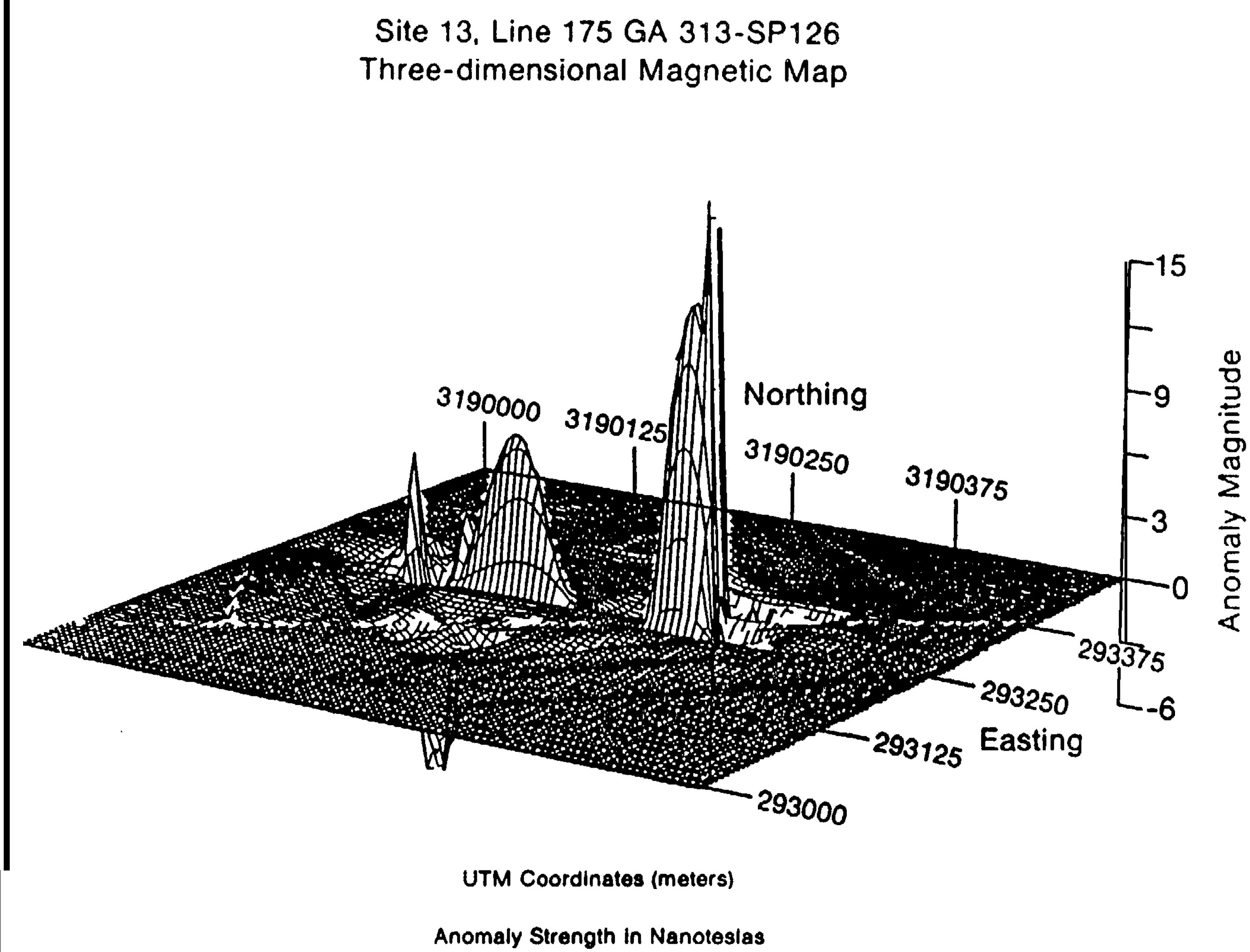


FIGURE II-86. **Contour plot of site 13, 175 GA 313.**



F GUR≤ -87. Three dimensional plot of site 13, 175 GA 313.

14.1.4.8 Site 14, Line 185 GA 313-SP145

This is a cluster of anomalies with a dipolar feature of 50 nT (Appendix K, Figure K-14b) and adjacent anomalies (Appendix K, Figure K-14c,d) of lesser amplitudes.

The graphical presentations (Figures II-88 and 11-89) give a good view of the spatial relationship as well as the distinct localities of the sources. The difference in amplitudes militate against an interpretation of the features as cable, chain or pipe. The impression is one of scattered debris that is buried as groundtruthing by divers found no exposed materials or metal detector readings.

14.1 .4.9 Site 18, Line 202 GA 313-SP118

This side-scan sonar contact and magnetic anomaly is a good example of the type of marine debris located within an offshore structure toss zone. The source was identified as a two door refrigerator (Appendix K, Figure K-18a). This is not so apparent without the observation of the groundtruth divers. One could never determine the character of the feature from the magnetic data alone (Appendix K, Figure K-18b,c) even with the perspective of graphics (Figures II-90 and 11-91). What is of note is the detectability of the localized magnetic signature against the larger gradient of the nearby platform.

14.1.4.10 Site **19,** Line 205 GA 313-SP115

This side-scan sonar contact and magnetic anomaly was identified as a 55 gallon steel drum with assorted debris such as beer cans and wood associated with it. Its sonogram (Appendix K, Figure K-19c) shows a distinct image at 100 kHz. The magnetic signature is of a distinct dipole **of 29 nT (Appendix K, Figure** K-19a) when the sensor is directly over the object. When originally found the feature was only detected by side-scan sonar. The display of the data acquired during relocation prior to groundtruthing dives (Figures II-92 and II-93) shows a localized anomaly of minimal duration and amplitude consistent with expectations of a source such as this.

14.1.4.11 Site **20, Line 207 GA 313-SP147**

This side-scan sonar contact and magnetic anomaly was found to be another barrel. Its magnetic and sonar signatures are identical to those seen for site 19 (Appendix K, Figures K-20a-d) (Figures II-94 and II-95). The dipolar signature diminishes in amplitude within 30 m of the source making it magnetically invisible to surveys using linespacing of 50 m or more.

14.1.4.12 Site 21, Line 229 GA 313-SP108

Detected only by magnetometer during resurvey (Appendix K, Figure K-21a) (Figures H-96 and II-97) relocation signatures of this 6 m pipe were consistent with those expected for an object of this type (Appedix K, Figure K-21 b-d). As the pipe was buried in 15-20 cm of mud it could only be relocated by probing and the use of a metal detector.

Graphical display of the data shows a sharply linear feature.

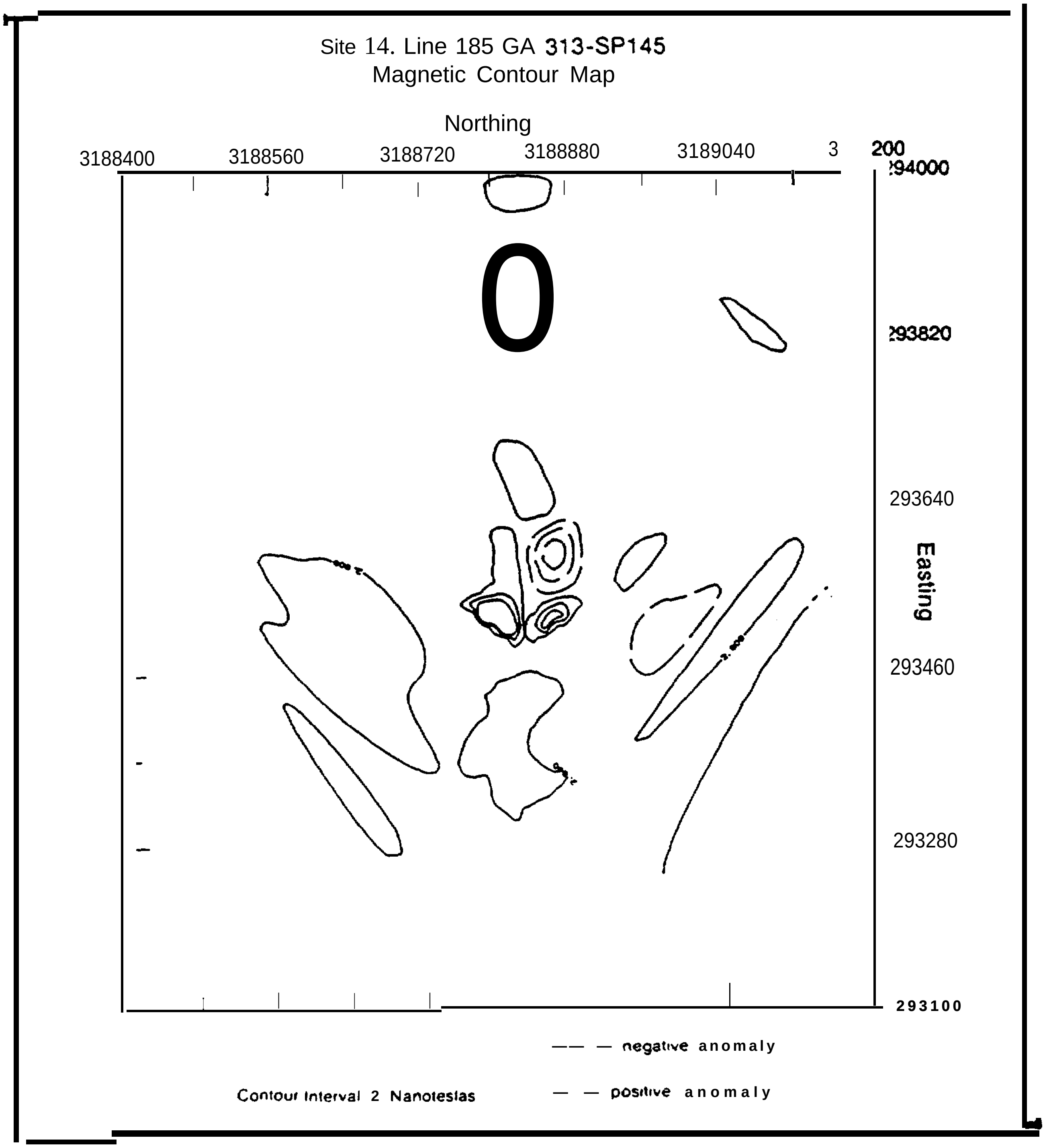


FIGURE II-88. Contour plot of site 14, 185 GA 313.

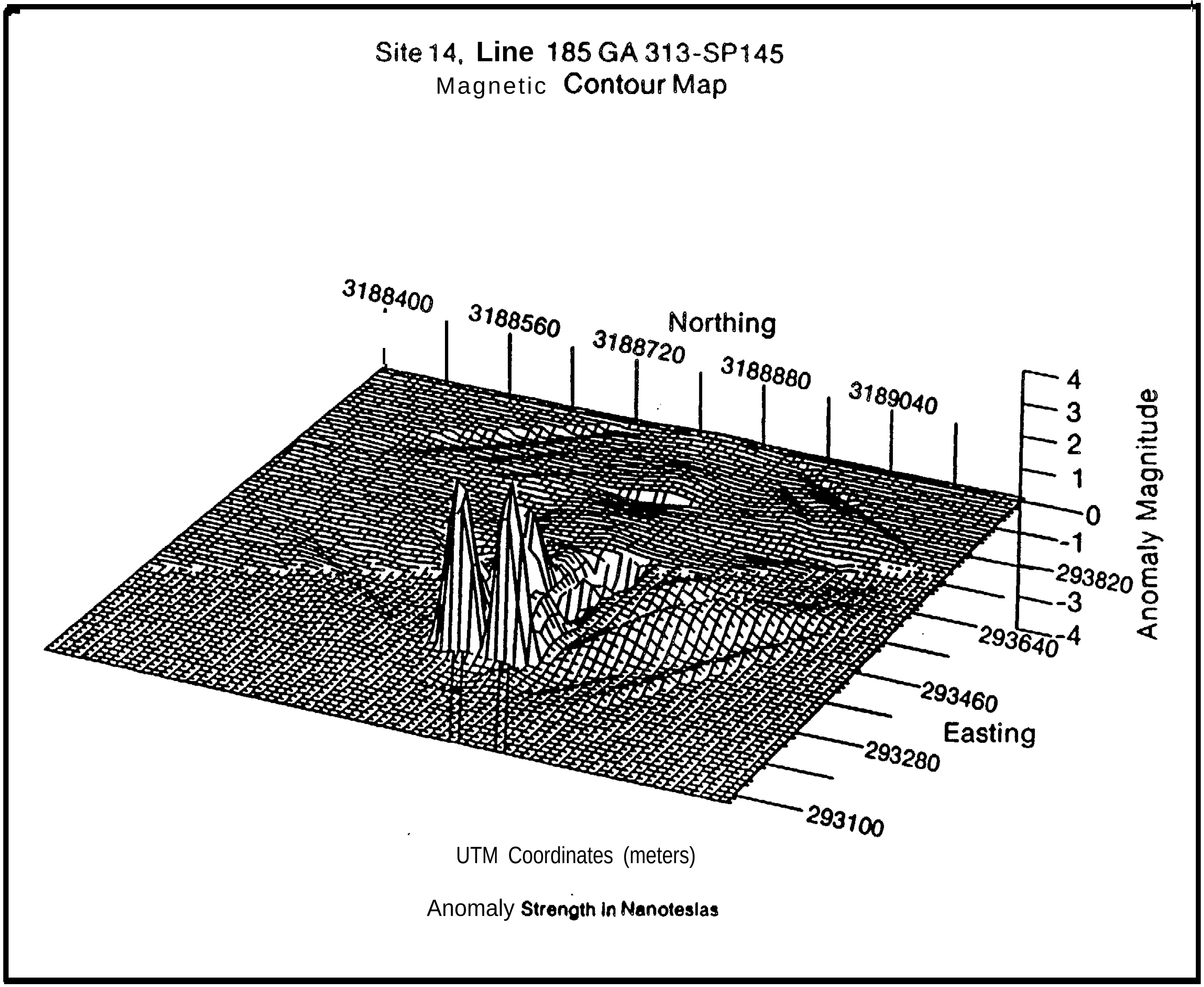


FIGURE II-89. Three dimensional plot of site 14, 185 **GA** 313.

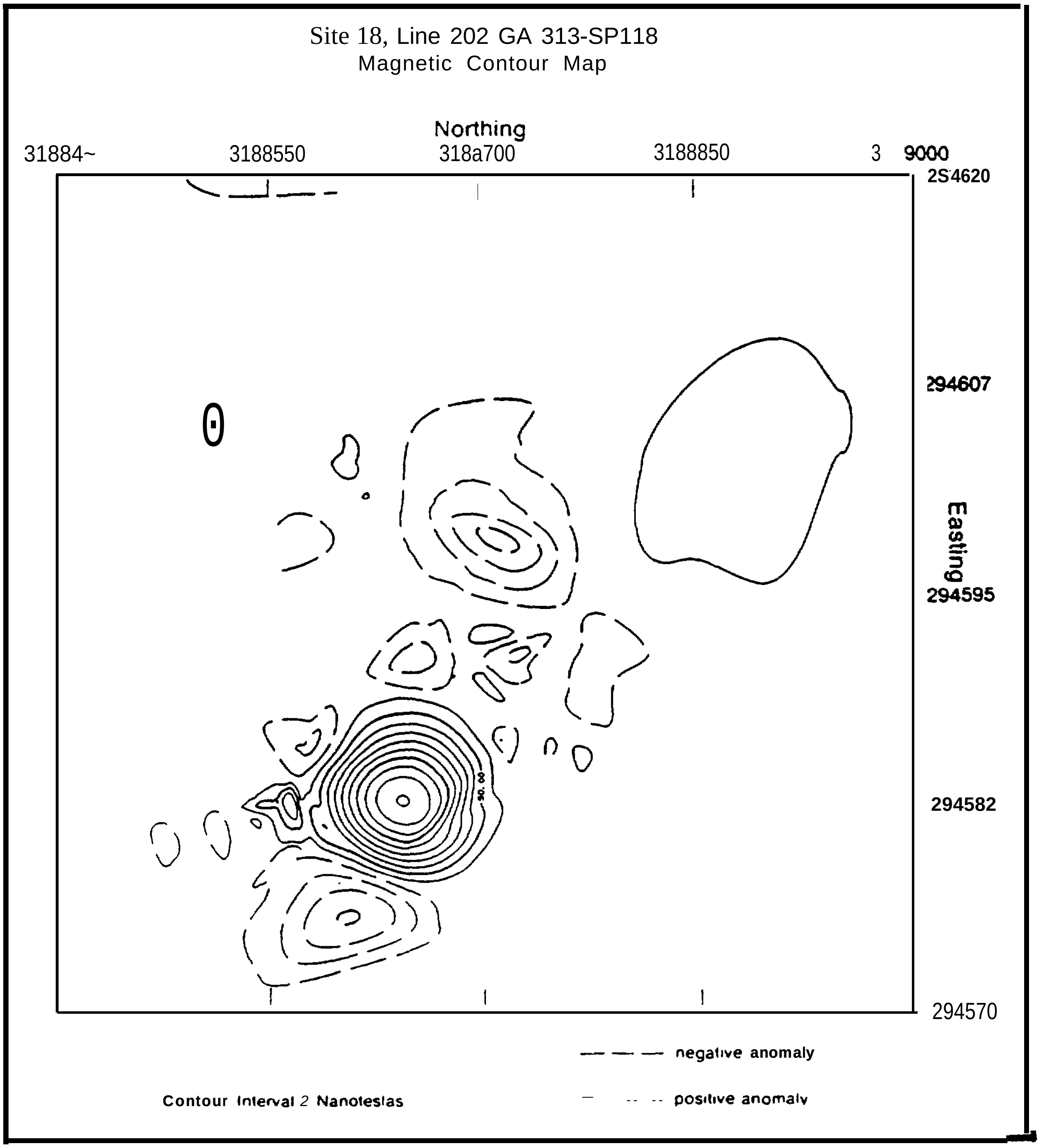


FIGURE II-90. Contour plot of site 18, 202 GA 313.

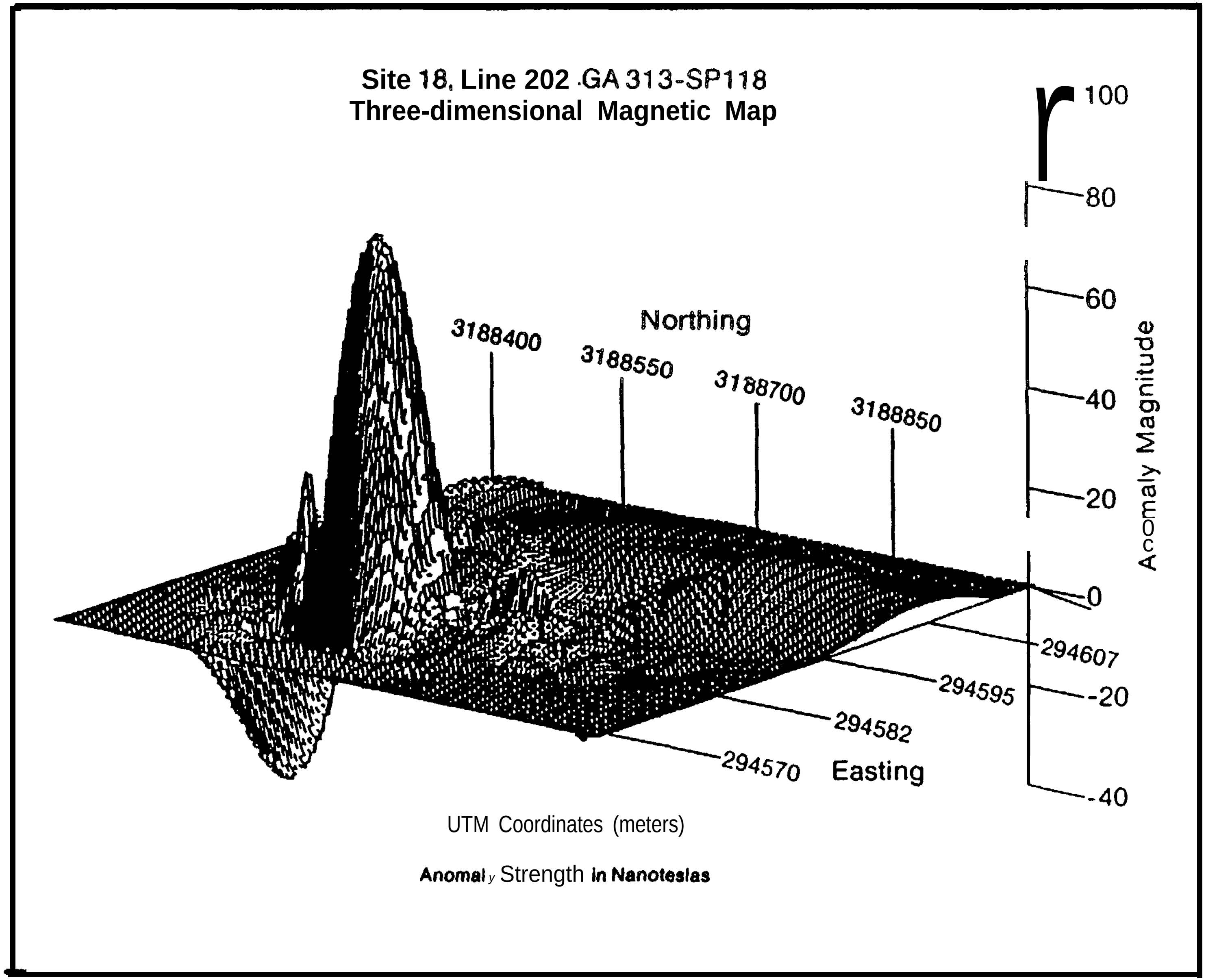


FIGURE II-91. Three dimensional plot of site 18, 202 GA 313.

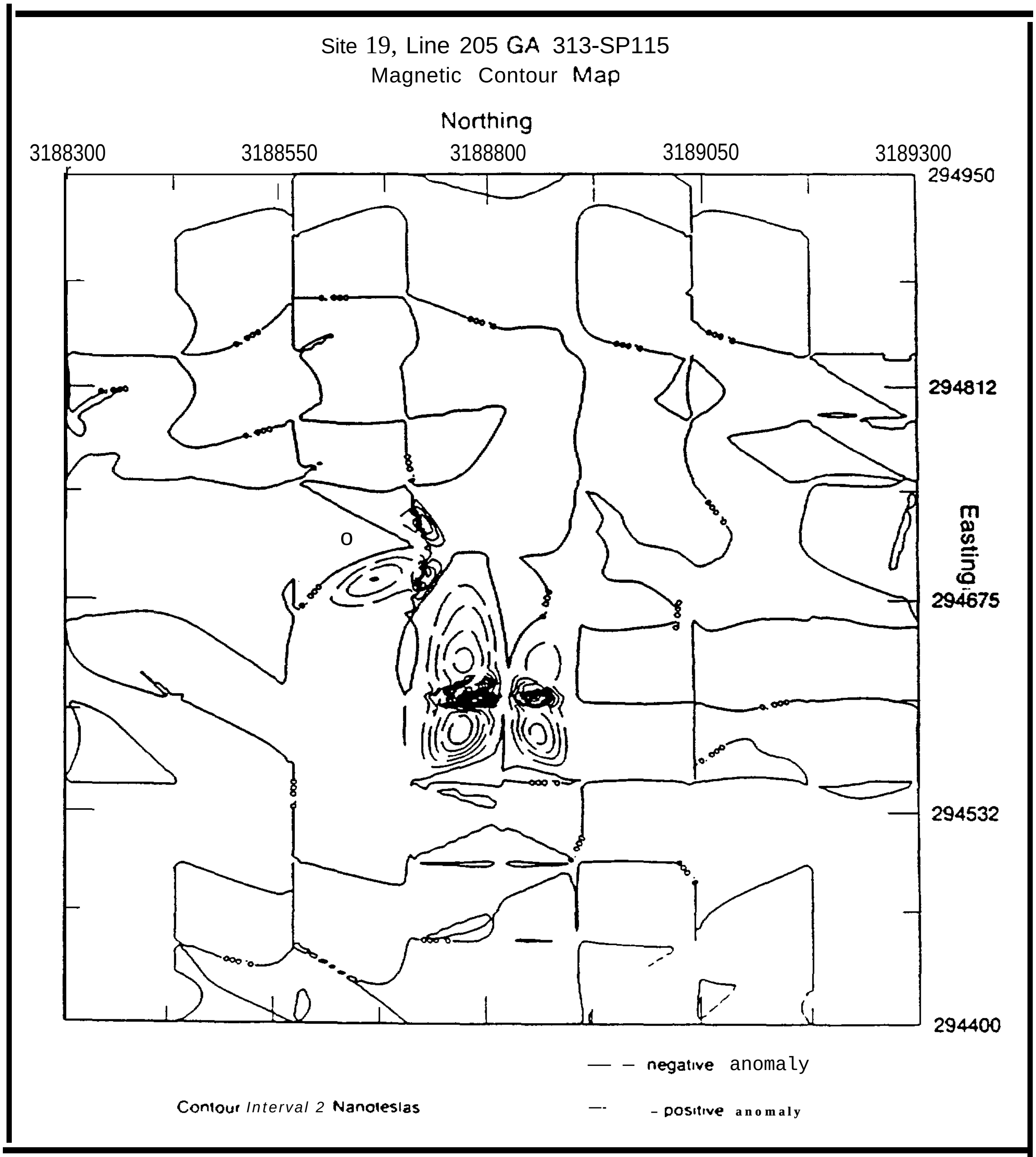


FIGURE II-92. Contour plot of site 19, 205 GA 313.

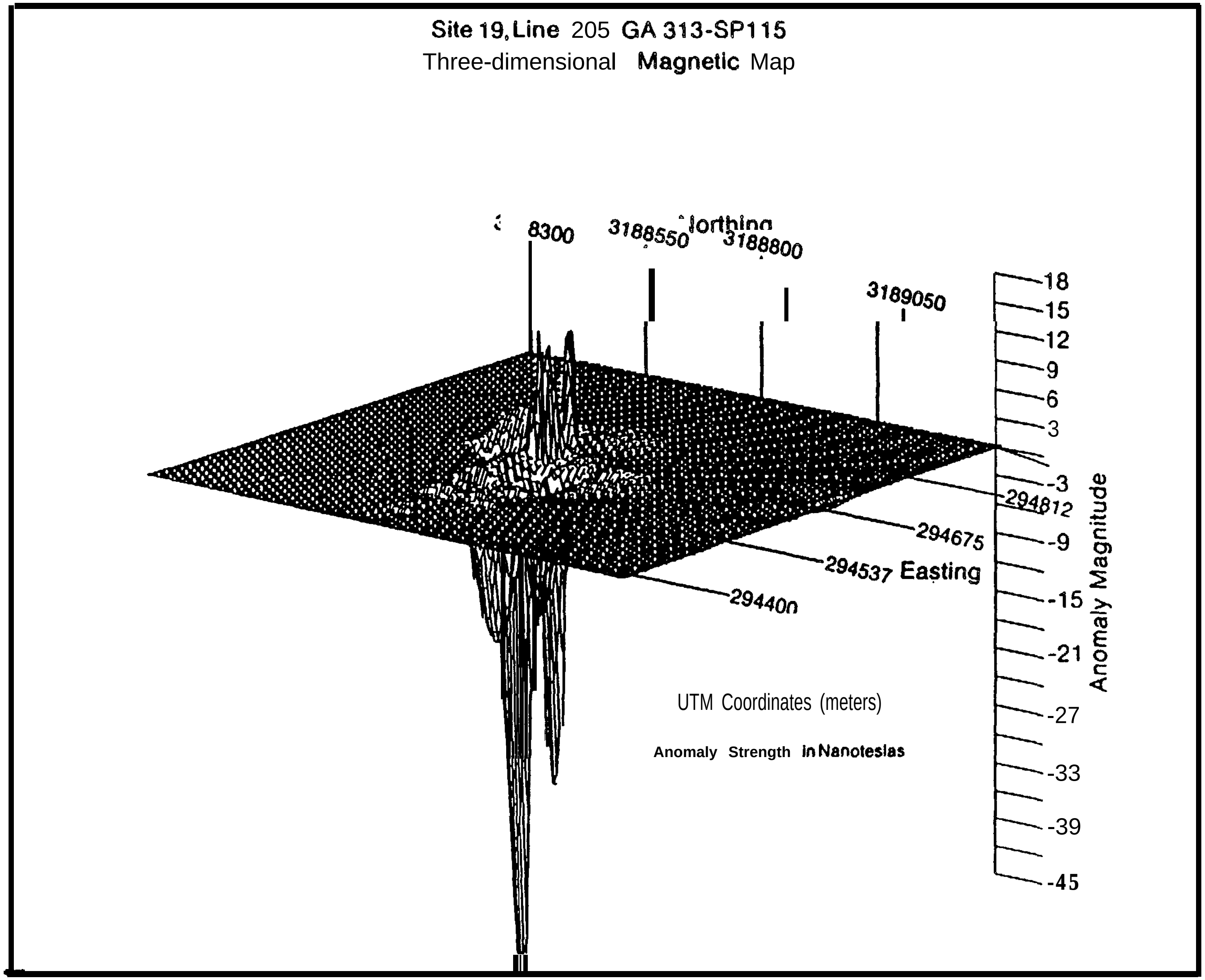


FIGURE II-93. Three dimensional pie! of site 19, 205 GA 313.

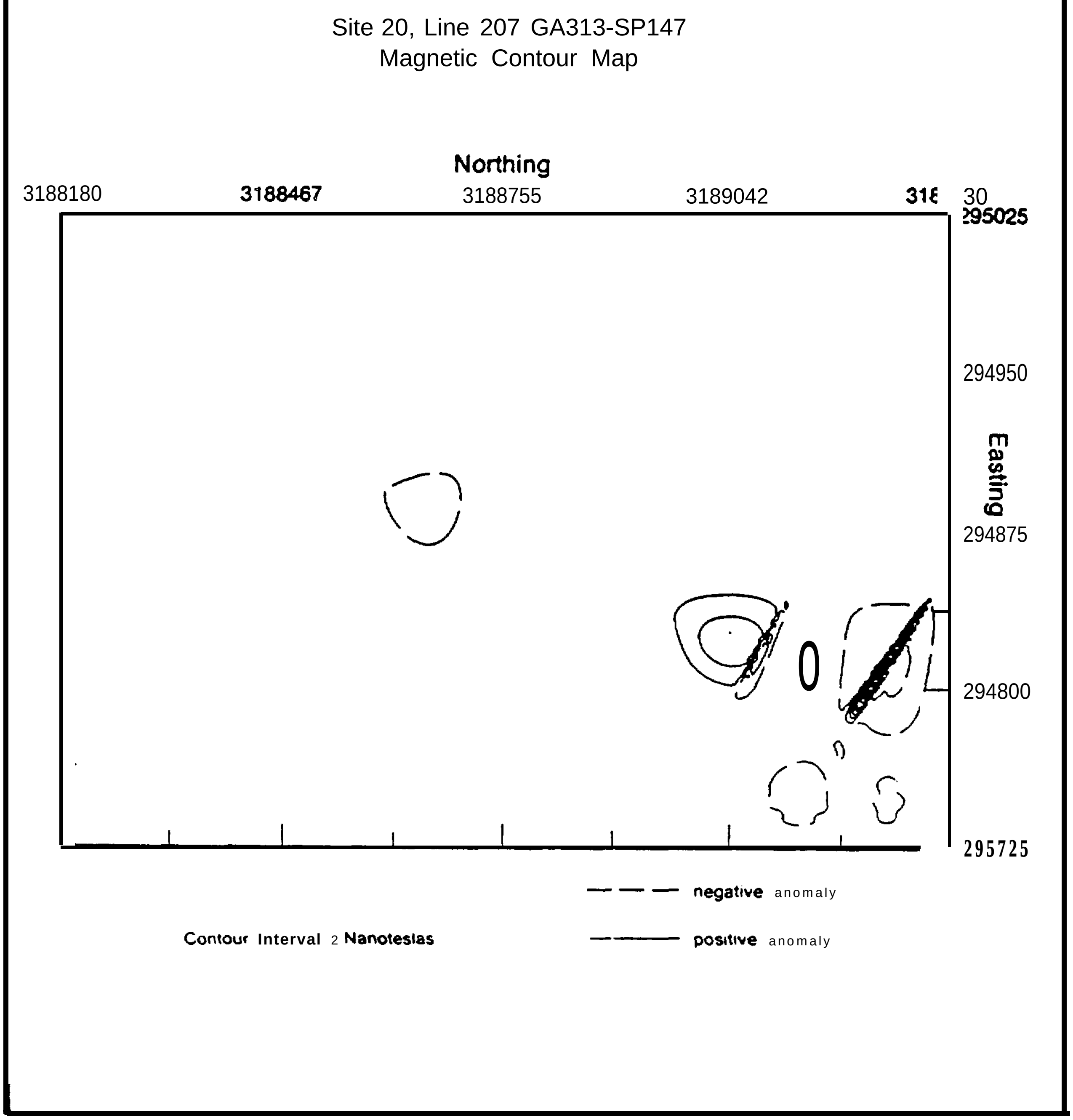


FIGURE II-94. Contour plot of site 20, 207 GA 313.

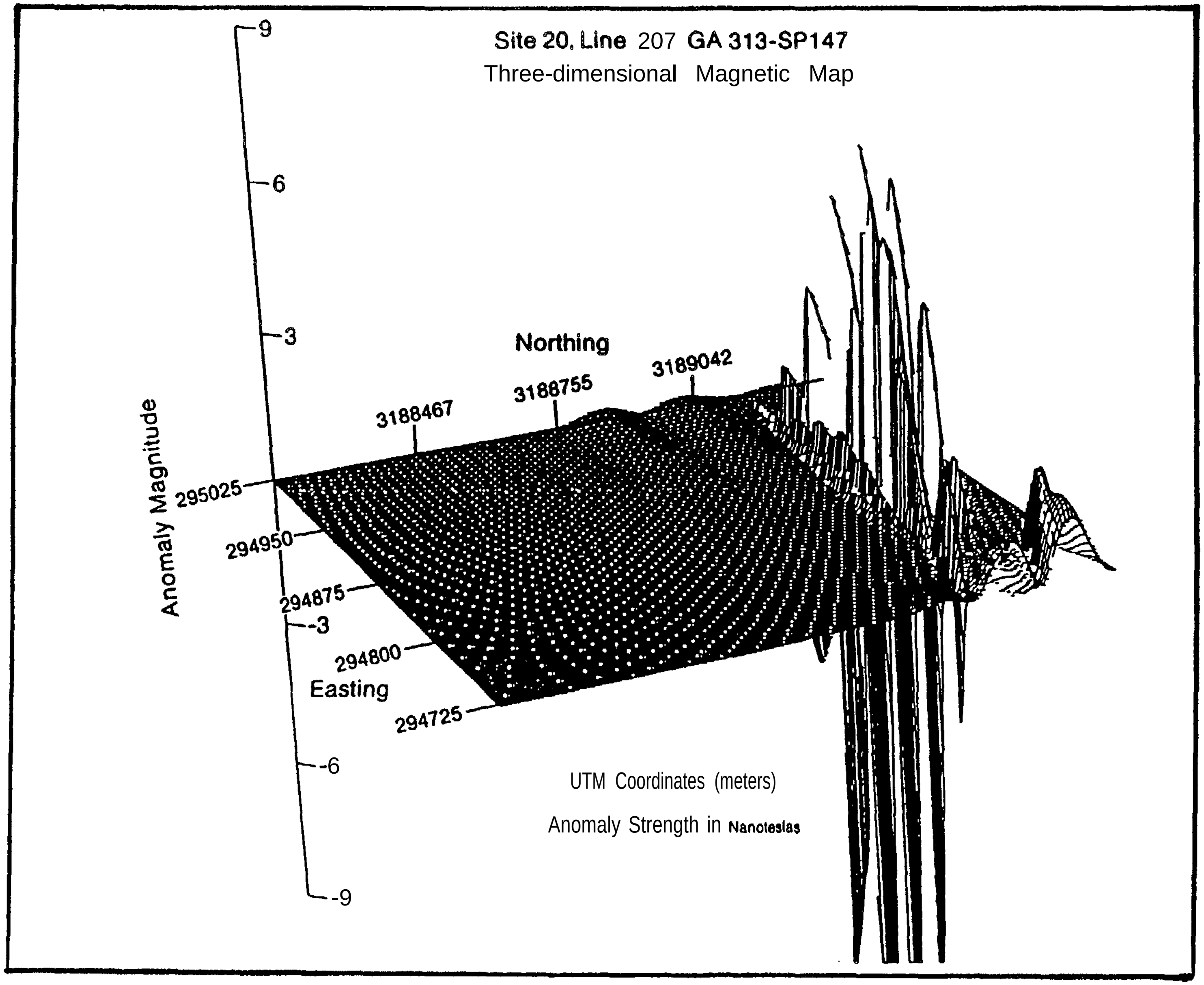


FIGURE II-95. Three dimensional plot of site 20, 207 GA 313.

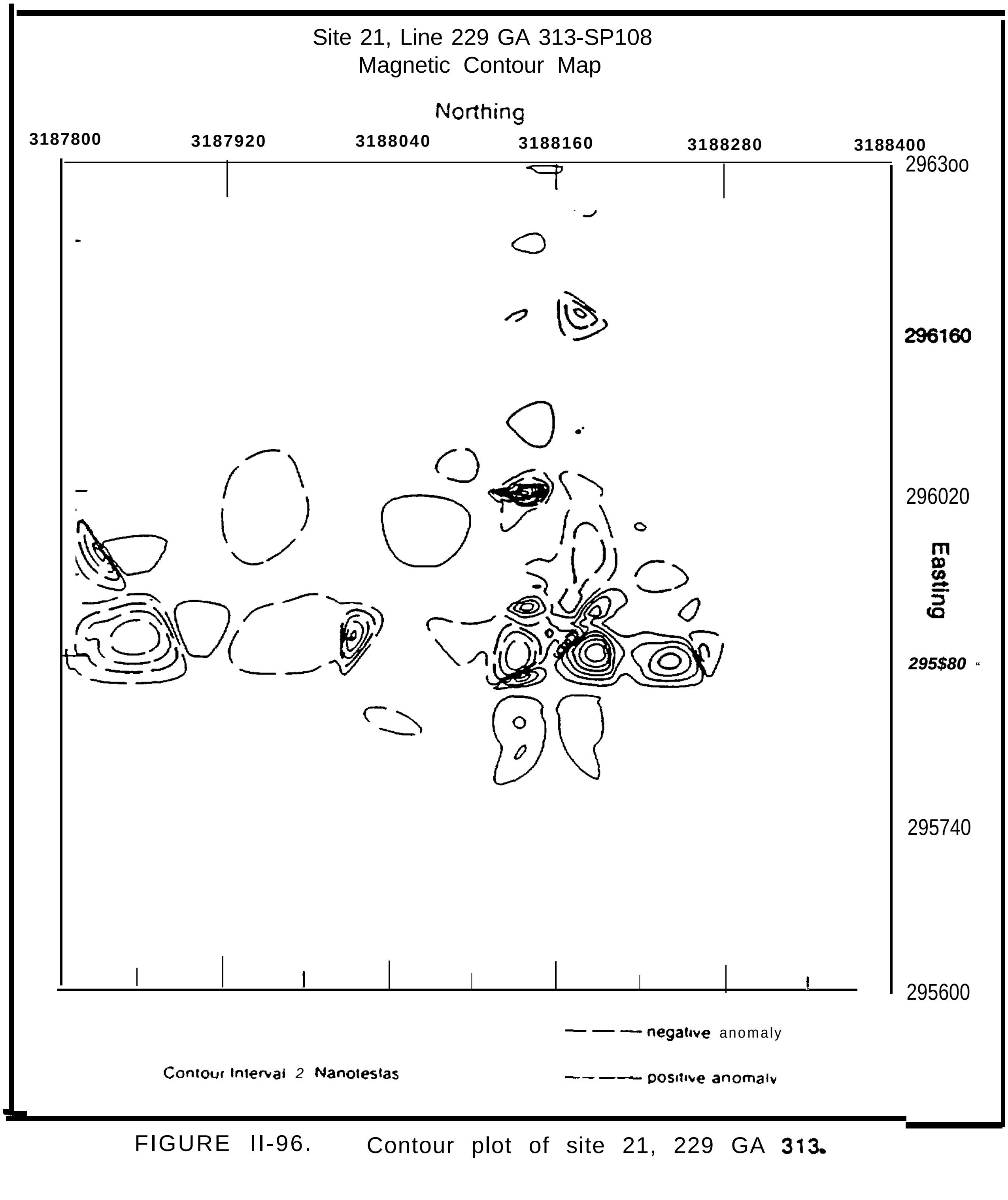


FIGURE II-96. Contour plot of site 21, 229 GA 313.

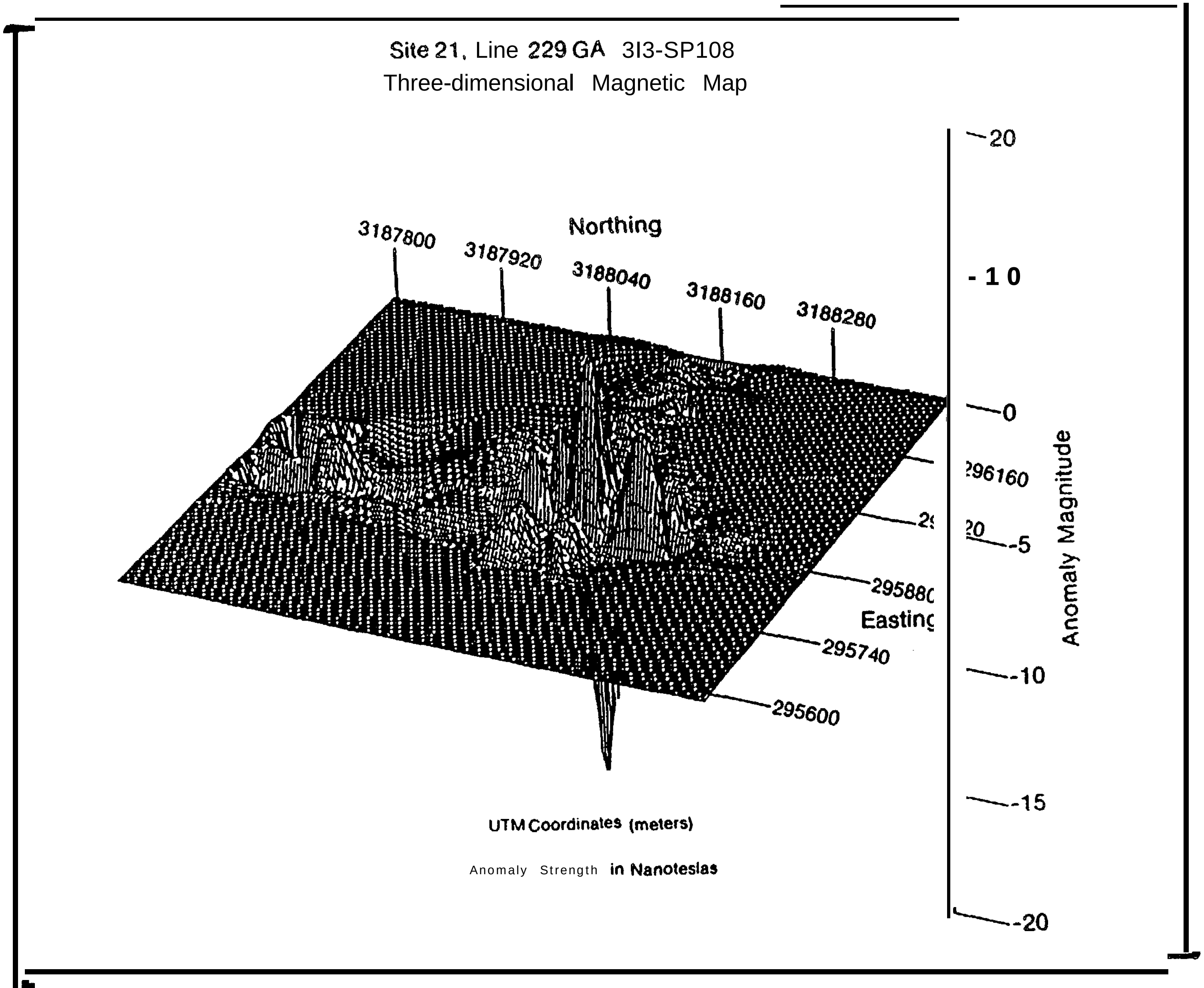


FIGURE II-97. Three dimensional plot of site 21, 229 GA 313.

14.1.4.13 Site 23, Line 305 GA 332-SP110

This side-scan sonar contact and magnetic anomaly represents the only shipwreck element found during the study within the three lease block areas. It was found on an east-west tie line and was seen as a magnetic dipole of low amplitude (Appendix K, Figure K-23a) but of some duration (41 m). It was not detected by the side-scan sonar during resurvey and only seen during relocation. The reason for this, we believe, was the fact the object was directly under the survey vessel and not picked up in the secondary sonar signal lobes or the object was perpendicular to the path of the towfish. The object was identified as the main mast of a modern shrimp trawler. The overall length was eight meters with assorted cable, chain and debris (buckets, cans) associated with it. The data (Figures II-98 and 11-99) shows a highly localized dipolar feature. The graphic displays of the relocation data presents a picture of a linear magnetic feature similar to that seen for the pipe at Site 21.

14.2 Anomaly Characterization and Pattern Recognition of Modern Ferromagnetic Debris and Potential Cultural Resource.

Arnold (1975, 1980, 1982) and other workers (Bevan 1986; Garrison 1981, 1986; Mistovich 1983; Saltus 1986 and Weymouth 1986) have written on the problem of discriminating marine debris from cultural resources or shipwrecks. Arnold (1980, 1982) has groundtruthed over 60 anomalies, 17 of which were shipwrecks of various periods. Irion (1 985, 1986) examined 33 anomalies in Mobile Bay two of which were shipwrecks. Gearhart (1988) located two shipwrecks during a magnetic survey of Ocean Beach in California. Stickel (personal communication) surveyed and groundtruthed the remains of a 1925 harbor tug in Los Angeles Harbor. Based on such a growing set of empirical data and that contained within this study some characterization or pattern recognition can be derived for shipwrecks and modern ferromagnetic debris.

In terms of the goals of this study, the question of anomaly characterization and pattern recognition is really a series of questions relating to the specific methodologies:

1. Can one differentiate, with a high confidence level, between modern ferromagnetic debris and potential cultural resources using present MMS survey methodology?

2. Can we differentiate, with a high confidence level, between modern ferromagnetic debris and potential cultural resources using a methodology such as that used in the present study--50 m or less survey intervals and groundtruthing?

The opinions of several of the authors such as Arnold, Saltus, Gagliano (CEI 1977, Vol II), Ruppe (1982) and others, suggest the answer to the first question is no except in the most obvious cases.

Saltus (1 986) effectively critiques the present MMS criteria to differentiate debris from shipwrecks. The principal reason for the lack of success in finding shipwrecks using the present methodology arises from the burial context of the historic shipwreck. As Arnold (1 980, 1982) states:

> "...there are those who advocate that if there is no side-scan target then there is no wreck...In groundtruthing 47 significant anomalies in Texas waters, only six cases, or about 13 percent, showed any debris protruding above the bottom ."

Most historic shipwrecks are buried and preclude detection or discrimination using side-scan sonar. The decision as to whether the shipwreck is present turns is based on the ambiguous

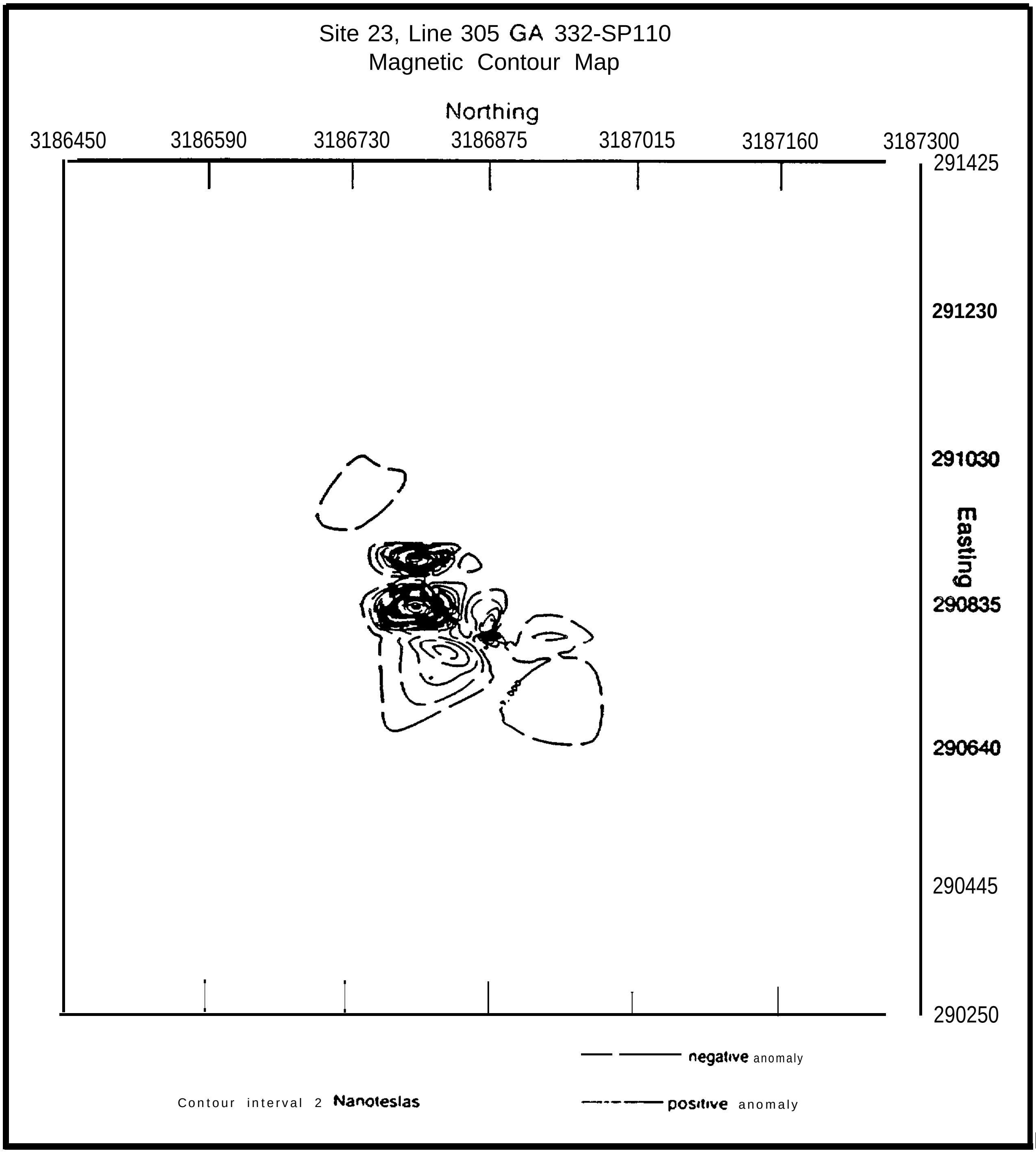


FIGURE II-98. Contour plot of site 23, 305 GA 332.

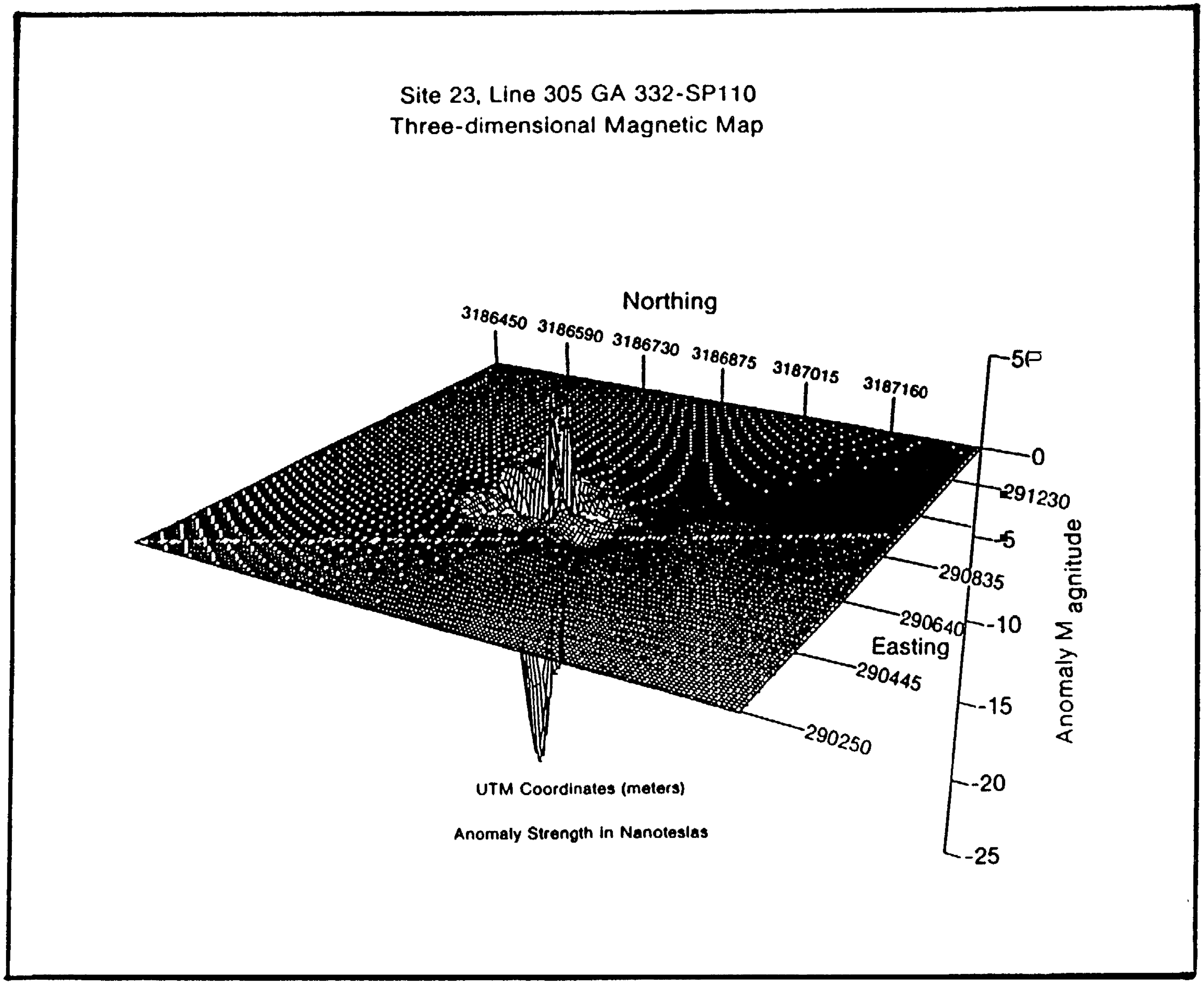


FIGURE II-99. Three dimensional plot of site 23, 305 GA 332.

nature of a single line or two of magnetic data. This has not been sufficient so the discovery success of the present MMS survey methodology as required in NTL 75-3 has been expectedly low.

The answer to the second question is more positive if the present study's methodology is used. Reliance on a closer grid interval or linespacing alone will increase the success in anomaly identification. If we rely on instrumental data alone, then the line interval of the survey is critical. This traces directly from principles in archaeomagnetism and from our present day correlation of variables in archaeomagnetism as they relate to specific sources.

Von Frese (1984, 1986) described a variety of archaeological sources, associated with historic terrestrial sites from an analysis of their geometries and relative amplitudes. Monopole anomalies, for example, exhibit radially symmetric amplitudes that frequently indicate features such as wells or pits. Dipolar anomalies are characterized by two signatures of opposite sign and unequal magnitude. These are generally affiliated with iron artifacts, hearths, bricks, tiles, etc. Structural features, such as trenches and walls, may exhibit weakly dipolar signatures and linear trends. Von Frese (1986) concluded that the majority of dipoles in historic sites exhibit large amplitude, short duration anomaly geometries with distinctive remanent magnetization components that are characteristic of *near-surface iron objects.* The directions of the remanent moments, as indicated by the location of smaller peaks relative to larger peaks, tend to be quite arbitrary for these sources.

Arnold (1980, 1982) has presented a body of data in the form of magnetic profiles taken over a suite of identified archaeomagnetic sources. No attempt has been made to apply the formulae for amplitude determination and spectral analysis discussed by Breiner (1973, Sections 14.1 .1.2 - 14.1.1 .4; and Von Frese, Appendix L). What is missing in Arnold's presentation is a display of the spatial relationship between the adjacent profile lines. This spatial character of the magnetic data allows us to resolve size and shape within a magnetic feature or features. This relationship of magnetic signatures and spatial distribution is at the core of determining patterns for shipwrecks and the discriminating these patterns from those of ferromagnetic debris.

We agree with Von Frese in his conclusion that the majority of dipoles or archaeomagnetic , anomalies are derived from near surface iron objects. This is true for shipwrecks as well as historic land structures. Arnold (1982) has explicitly taken the magnetic data from such sources and defined what he terms a "classical shipwreck signature."

> "The anomaly showed up on six tracks, which suggested a large mass of iron. During relocation the fathometer indicated an object rising above the bottom with associated scour depression." (Arnold 1982).

For this characterization Arnold (1982) used a lane spacing of 50 m. He states further:

> "The pattern of anomalies on adjoining survey tracks is the key to identifying significant anomalies and distinguishing them from those far more numerous anomalies caused by isolated iron debris, which often show up on only one track."

The pattern of anomalies is thus one key to discriminating between anomalies associated with historic shipwrecks and debris. Arnold (1982) presents the caveat that not all anomalies distinguished by the pattern of readings he describes will be shipwrecks. Large objects such as discarded wire cable can produce similar anomalies. Indeed, we have seen this to be true with the results of this study, although graphical presentation of the profile data showed a spatial pattern that may be associated with cable or wire (Figure II-32). Arnold concludes that physical examination is the only way to determine the cause of anomalies as remote sensing data is rarely sufficient to stand on its own.

Mistovich (1 983) has defined a pattern for magnetic readings indicative of a shipwreck which has broken apart and scattered its cargo over a wide area. He defines this pattern as a cluster of “three or more anomalies within an area of 50,000 m.” This area is not as great as it first seems representing the square of approximately 225 m. Mistovich admits that the definition is probably too liberal for the more concentrated wreckage which could be expected in protected environments as opposed to an active coastline (Irion 1986). Mistovich's model was developed for the Texas coast, a high energy environment capable of dispersing material over a large area.

Clausen and Arnold (1 975; Figure II-1OO) have presented a three-dimensional graphic plot of the wreck of a 16th century Spanish vessel lost on the lower Texas coast. This ship is a small 150-250 ton nao. It shows a scatter of ferrous components extending over an area of 10,000 sq m (CEI 1977, Vol II: 82). Clausen (1966) reports that it is not unusual to encounter shipwrecks that cover as much as 100,000 sq m although 50,000 sq m is more common. This is clearly the basis for Mistovich's cluster pattern model.

Garrison (1986) has presented magnetometer data of a 19th century shipwreck, WILL O’ THE WISP lost off Galveston Island, Texas. Shown in Figures II-101 and II-102, this shipwreck’s archaeomagnetic area is roughly 55,000 sq m. Groundtruthing studies of this shipwreck presented a pattern similar to that outlined by Arnold, e.g. the shipwreck is detected as significant anomalies on multiple lines. Fathometer readings showed an object or objects above the bottom with an associated scour depression parallel to the axis of the vessel. Divers recorded the remains of a fire tube boiler, a spider gear or flange and the line of a partially exposed strake (Figure II-103).

Anuskiewicz has presented magnetometer data on another 19th century vessel, GIL BLAS, sunk off Hillsboro Beach, Florida (Anuskiewicz n.d.). Shown in Figure II-104, we see a distribution of archaeomagnetic anomalies over 10,000 sq m concentrated in the upper quarter of the contour plot of the site.

Gearhart (1988, 1989) presented definitive graphical representations of two shipwrecks from Ocean Beach, San Francisco, California (Figure Ii-l 05). Gearhart (1988) expressly evaluated his data using Delgado and Murphy’s (1 984) hypotheses concerning anomaly patterning for environmentally exposed shipwreck sites (Gearhart 1988). These hypotheses or expectations for beach zone wrecks have merit in our consideration of the larger class of near and offshore sites. The methodology used in the Gearhart study is best styled as mid range theory building--the construction of bridging arguments between observed physical variables and the interpretation of the archaeological record or context (Schiffer 1975; Leone 1988).

In their models for anomaly patterns, Delgado and Murphy (1984) define these types of wrecks - (1) buoyant hull; (2) buoyant hull fracture; and (3) buoyant structure (Gearhart 1988). Type 1 is an intact or articulated remains of a ship’s hull whose anomaly pattern is expected to be a linear series of anomaly peaks. Type 2 represents a pattern of a multiple anomalies due to hull breakup and debris scatter. This pattern has been observed with wreckage of a Civil War anti-torpedo craft on Mustang Island, Texas where debris radiated landward from the principal wreckage (Smith, et. al. 1987). The suspected site of GIL BLAS (Figure II-44) represents a Type 2 pattern. Type 3 represents a scatter of wreck fragments no longer in close association. The pattern is scattered anomalies over an area of several kilometers. This pattern is that observed by Matheson (1 988) for the ATOCHA. It would be plausible for any ship lost in a high energy, high current environment.

Gearhart’s plots (Figure II-105) are of Type 1 (KING PHILLIP) and Type 2 (REPORTER). An interesting speculation that arises from this model is the probable transitition of site patterns over time in high energy environments and the pattern expected for wrecks in low energy zones.

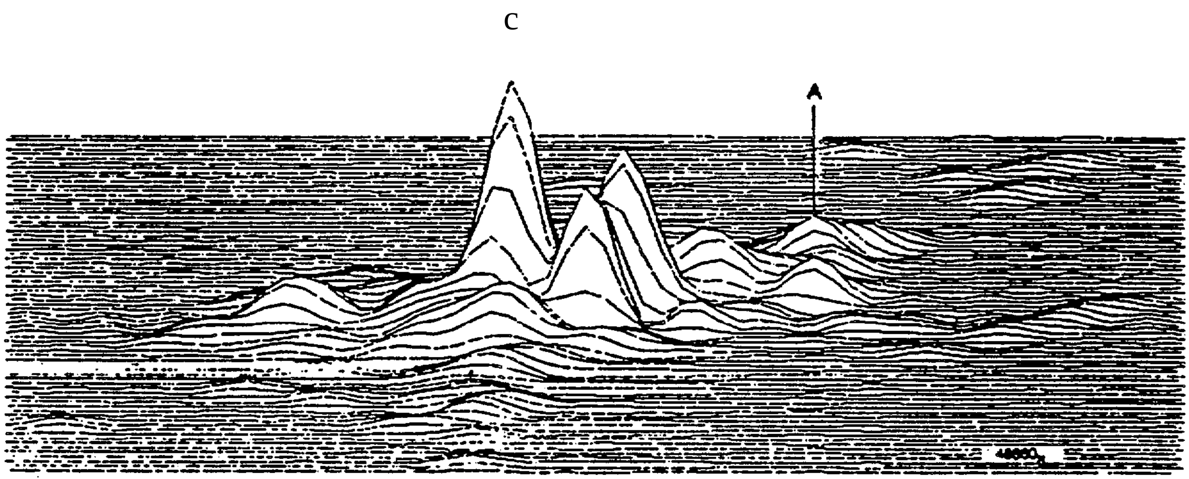


FIGURE II-100. Three dimensional plot of 16th century ship (after Clausen and Arnold 1975).

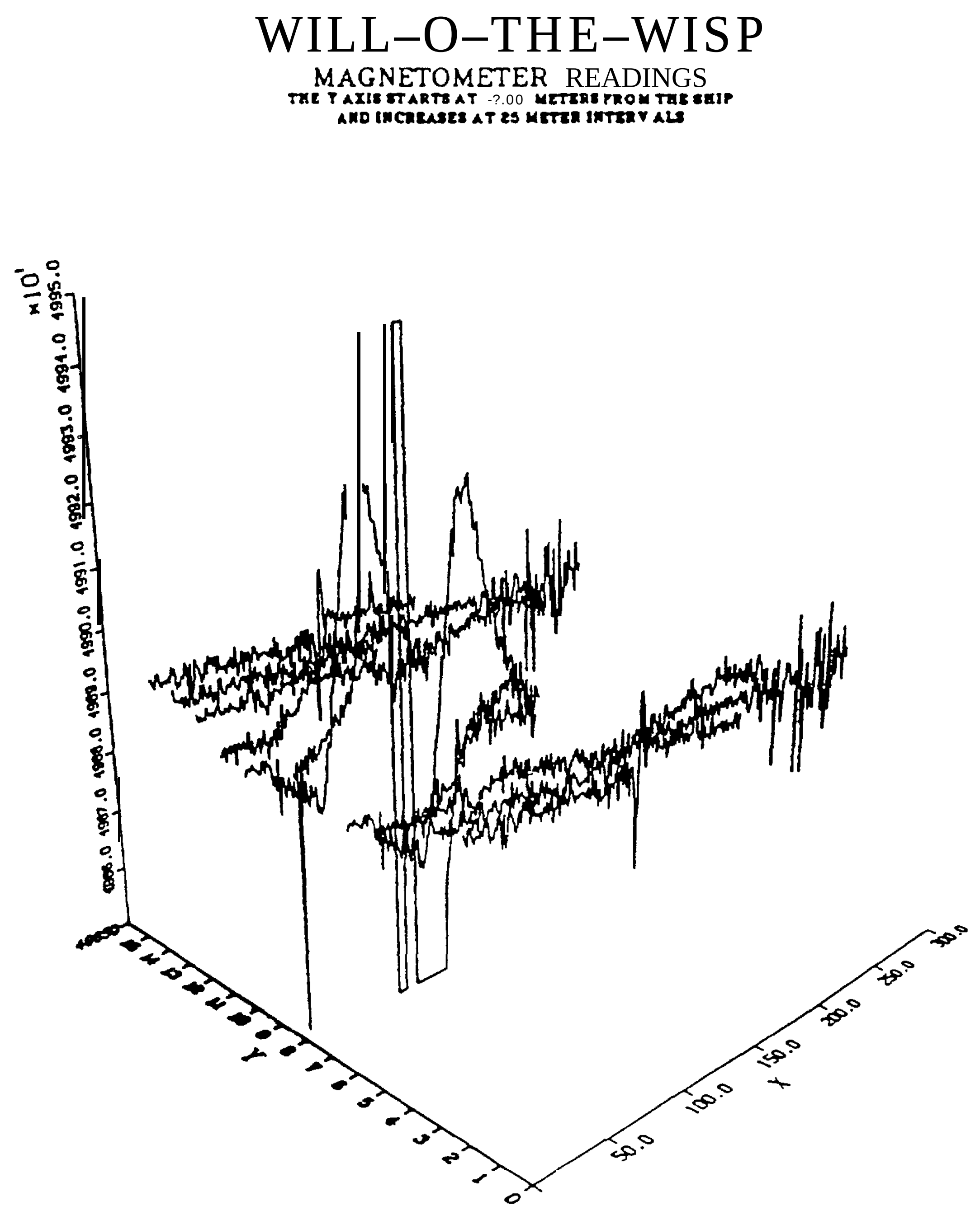


FIGURE II-101. Magnetic profiles, WILL O' THE **WISP.**

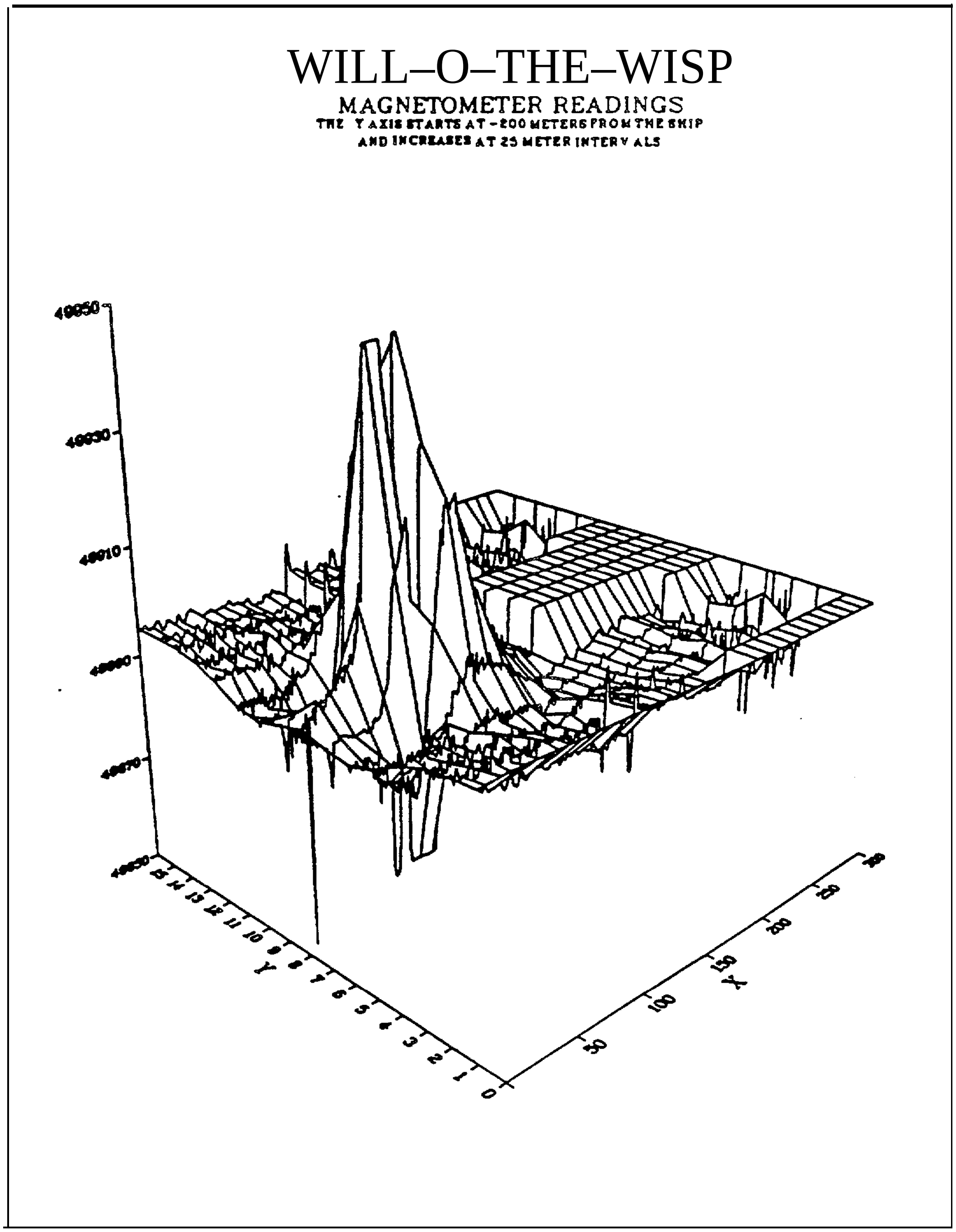


FIGURE 11-102. Three dimensional plot of magnetic anomalies of the WILL 0° THE WISP.

FIGURE II-103 View of machinery of the WILL O' THE WISP (Courtesy Larry R. Martin)

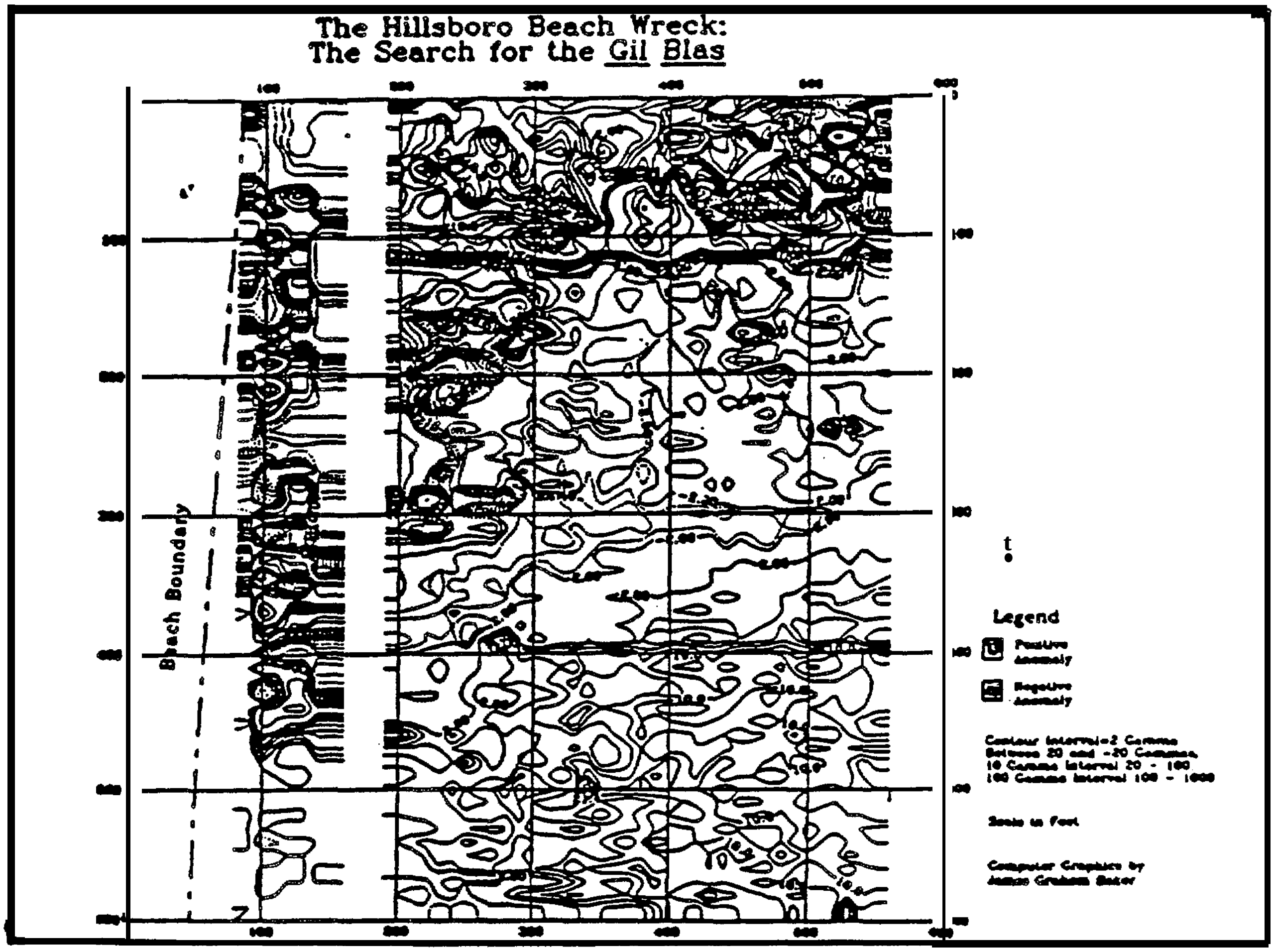


FIGURE II-104. **Contour plot of the Hillsboro Beach Wreck (Courtesy** Rik **A. Anuskiewicz).**

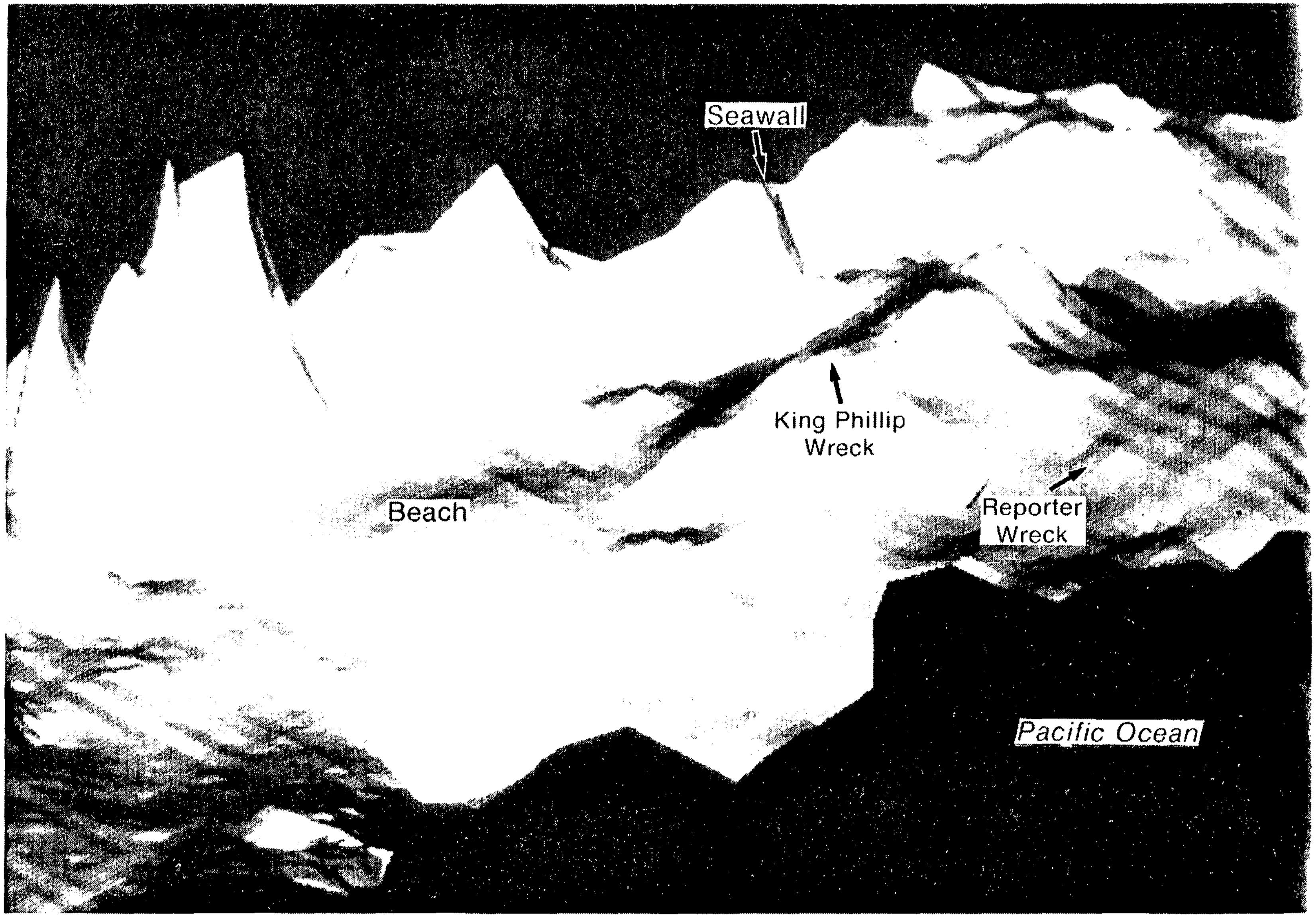


FIGURE 11-105 **INTERGRAPH three-dimensional plot of the KING PHILLIP and REPORTER wrecks, Ocean Beach, California (Courtesy Espey, Huston & Associates, Inc.)**

Common to most of these examples is the pattern articulated by Arnold, Arnold and Clausen, Mistovich, and others that a shipwreck as an archaeomagnetic feature can be defined as *a cluster of multiple anomalies within an area of 50,000 sq m or less.* As a working definition it rests on a growing body of empirical data which seems to support it. Isolated anomalies over a large spatial area with little or no expression on adjacent survey lines of reasonable width will, in most *instances,* be marine debris. We have seen this in this study. The one shipwreck element, a steel mainmast, did not fall on adjacent survey lines but is an artifact of the survey methodology where tie lines were not surveyed at the 50 m linespacing used for the principal grid. Groundtruthing survey lines run at 10 m intervals suggest the mast would have been seen on adjacent lines and certainly it would be seen as a sonar contact. That it could be discriminated as an element of shipwreck based on instrumental data alone is not plausible because the feature is a pipe, albeit one that was a structural element of a vessel. Its anomaly signature is that of a pipe (Figures II-97 and II-98). Only verification by divers ascertained its identity as a part of sunken vessel.

Another anomaly found by this study, a coil of cable, mimics the pattern defined for a shipwreck by Arnold. Although the graphical display of the magnetic profile data suggests the probable nature of the feature, diver inspection increases our analytical understanding even more so. The equality of the disparate anomalies do suggest that the cable feature could be differentiated from a shipwreck which typically demonstrates more irregularity in its multiple anomaly peaks. Uniformity of amplitudes point away from an interpretation of a multiple anomaly feature as a shipwreck.

In the present study, the bulk of anomalies detected and groundtruthed were modern ferromagnetic debris. One shipwreck structural element was found. The fact that it was a modern wreck does not diminish the fact that out of 20 anomalies groundtruthed, one was a shipwreck artifact. Without groundtruthing however, we would have classified this artifact *as* modern ferromagnetic debris. Further, the remainder of the shipwreck may not be near the location of the relocated mast. This observation brings us to a consideration of a rather unique aspect of modern ferromagnetic debris--mobility or relocation.

Irion (1 986) reported that all the anomalies investigated in one Mobile Harbor survey were modern debris. One-third were steel cable discarded after being worn or broken. What is interesting is that Irion and his coworkers could not relocate 24 percent of anomaly positions originally seen in their instrumental survey. They posed two explanations for the absence of the anomalies from their recorded positions; first, their absence may have been the result of positioning error; or second, the anomalies had been removed between the original survey (1982) and groundtruthing (1985). Their conclusion was that the second explanation was more plausible due to the high number of shrimp trawlers fishing their survey area. Informants told them that shrimp nets are drug an inch below the mudline thereby snagging anything lying directly on the bottom. Shrimpers would dump anything snagged in their nets causing a constant movement of material.

We have observed the same phenomenon in the Gulf. Several significant anomalies (seven out of 28) were not relocated. This represents a 25 percent portion of our sample selected for groundtruthing study. Our explanations are those of the Mobile study--positioning error or removal. We discounted positioning error after relocation of some of the smallest anomalies and sonar contacts. Further, recalibration at control points used on the March (1988) resurveys and the August (1988) groundtruthing studies were consistently within the range of error of the positioning systems (1-3 m for the Del Norte X-band system and 5 m for the STARFIX system). Our conclusion was that the anomalies were moved by trawling activity between the two surveys.

What does this mean to the characterization of modern ferromagnetic debris? It is a characteristic of this debris that it is capable of being relocated or moved by fishing trawlers active year round in the Gulf. Portions of shipwrecks fall into this category as well, given our example of the shrimp boat main mast. In the recent case of the EL NUEVO CONSTANTE , the discovery was made by a shrimp fisherman who hung his nets on the wreck. The bulk of shipwrecks, by their mass and complexity, cannot be moved by trawling disturbance, but, as we have seen, elements such as the mast can be. We believe this also explains the lack of correlation in the number of anomalies seen on the original lease block surveys and our later resurveys. The anomalies are not there anymore. By extension, we can argue that this phenomenon is characteristic of only debris, primarily of a modern origin. We also believe the anomalies created do not mimic patterns expected for historic shipwrecks.

In summarizing this discussion of instrumental patterns of shipwrecks and modern ferromagnetic debris, these are some salient characteristics that can be used to confidently differentiate the two when given sufficient information:

Anomaly and Side-scan Sonar Patterns Characteristic of Historic Shipwrecks

1. multiple peak anomalies or spatial frequency;
2. differential amplitude anomalies;
3. areal distribution 210,000 square m;
4. long gradients and duration;
5. axial or linear orientation of anomalies;
6. scour areas associated with anomalies;
7. exposed structure is geometrically complex and associated with anomalies; and
8. relative locational permanence.

Anomaly and Side-scan Sonar Patterns Characteristic of Modern Ferromagnetic Debris

1. single peak anomalies or no spatial frequency;
2. few if any differential amplitudes;
3. localized areal distribution ≤1 0,000 square m;
4. sharp gradients and short duration;
5. random, non-axial orientation of anomalies;
6. scour areas with no associated anomalies;
7. exposed debris geometrically simple; and
8. locational transience.

In these pattern definitions the assumption is made that the methodology is one of 50 m or less lane interval. Groundtruthing is not assumed. Criteria One through Three are self-evident. Criteria Four and Five require some explanation as they relate to distance and speed. A survey speed of eight knots will produce a shorter duration signature than one done at four knots. The emphasis here is on the difference in overall duration even with this disparity. The amplitude duration will be longer in almost all cases when a shipwreck is involved. Fall off and duration is sharp for debris at almost all survey speeds. These debris also behave as point sources in terms of orientation. Criteria Six and Seven depend on the burial nature and breakup of the source. Shipwrecks are harder to bury than debris although numerous examples can be cited. Modern era shipwrecks are more likely to protrude from bottom sediments except near shore where wrecking and burial is accelerated by strong currents and wave action. Still in these environments, we can point to wrecks as the ARCADIA, WILL O'THE WISP, EL NUEVO CONSTANTE as examples where sonar images can demonstrate those features such as complexity and scouring. In each case of modern debris detected by our surveys, the features are geometrically simple. Scour patterns or scars, such as the leg scars of the jack-up rig or the anchor drags, are not complex. Absence of any one or more criterium does diminish our confidence in the identification of the feature but taken *in toto* the recognition of these criteria at a site increases our ability to discriminate the two classes of phenomena--shipwrecks and debris. The inclusion of groundtruthing enhances our ability to identify the two.

What weakens the recognition of these criteria is the use of a survey methodology at a wider spacing used in this study. Specifically, in the resurveys and in earlier tests, such as the WILL

O' THE WISP one cannot discern multiple peak anomalies on adjacent lines of 150 m distance. Differential amplitudes for anomalies cannot be confidentially discerned as the lesser anomalies are masked by larger ones. Duration can be guaged but generally only on one line. This allows debris to mimic archaeomagnetic anomalies without the discrimination available with multiple profiles. Orientation works to our disadvantage with single line anomalies. At distances over 50 m, orientation drastically affects fall off rates for anomalies. Of all the criteria, sonar images are least affected. In the recent relocation of the Confederate cruiser CSS ALABAMA the presence of a scour trench on the port side was a distinguishing feature in the instrumental data (Max Guerant, personal communication). If any unburied structure is present, a present day side-scan sonar system should detect it. In the absence of associated magnetic anomalies, it is difficult to characterize the contact.

Finally, using the existing survey methodology of 150 m linespacing can we characterize and differentiate modern ferromagnetic debris and potential cultural resources, such as historic shipwrecks, by means other than increasing survey coverage?

Authorities such as Arnold (1986), Bevan (1986), and Weymouth (1986) have suggested both technical and analytical methods. These include illustration of ail reported anomalies and intercomparison with data (such as Arnold 1980, Saltus 1980, and Rhodes 1980) obtained by groundtruthing or experimentation (Arnold 1986). Bevan (1986) suggested instrumental techniques for differentiating old iron from modern steel but the measurements cannot be obtained with instrumentation currently in use on lease surveys. Von Frese's (1986b) suggestions of reducing anomalies to the north geomagnetic pole or vertical polarization by use of first principles could facilitate the recognition of remnently magnetic features. Significant differences in the remnent magnetism may allow the discrimination of old iron from modern steel as Bevan suggests, The assumption is that a difference in remnant magnetism exists between the two facies of ferrous materials. This remains to be established by empirical study and is beyond the scope of this study.

Saltus (1 986) sees little improvement by retaining the present MMS analytical factors to discriminate between shipwrecks and debris. While it may not be analytically possible to contrast iron and steel by remnant magnetization one may be able to characterize anomalies as to their inductive magnetization. This component of an anomaly has a strong dependence on declination and inclination characteristics of the geomagnetic field (Von Frese 1986). The argument here would rely on the structural complexity of a shipwreck having a large or detectable inductive magnetization. Anomalies without this component could be classified as exclusively ferromagnetic features and by logical extension, debris. Again, this is an analytical approach that could improve the detection of and discrimination between classes of ferromagnetic materials and be used within the current methodology.

Another approach relying on numerical analysis of data obtained with the present methodology involves the statistical evaluation of variation in magnetic signatures. By returning to a simple display of the magnitude of the spatial frequency of anomalies, such as Clausen's 1966 example, it is possible to use this data in a calculation of diversity (Shannon and Weaver 1949) or Brillouin's variation of the same measure (Brillouin 1962). The Shannon-Weaver formula is:

$$H_{max} = \sum_{i=1}^{s} (P_i)\ (\log_2 P_i) \qquad \text{(Eq. 6)}$$

Where s = the number of classes
pi = the proportion of the sample in the ith class

Brillouin's variation is:

$$H = \frac{1}{N} \log \frac{N!}{N_1!\ N2!\ \quad Ns!}$$

(Eq. 7)

Where N = the total population in categories wherein members are represented proportionately as N_1, N2 . ..N_n.
S = the number of classes or categories

In Clausen's data s = 3. If we apply this formula to the Clausen data we have the classes S_1= 12 (low), S_2 = 12 (medium), and S3 = 22 (high), which yields a value of H equal to 0.32. This is a relative value with little to compare it to. To do this one applies a rank-order classification to a ferromagnetic debris site. Less complex, these sites should yield a diversity index significantly lower than that of Clausen's.

Using a suite of variables common to magnetic anomalies, a factor analysis was done to examine any pattern or associations that can aid in the discrimination of modern ferromagnetic debris and historic shipwrecks. Using data from this study and others (Clausen 1966; Clausen and Arnold 1975; Arnold 1980; Garrison 1986; and Anuskiewicz n.d.) it was possible to derive values for four variables: (1) number of peaks on an equal number of traverses of the feature; (2) an estimate of the anomaly area in sq m; (3) the anomaly duration as distance; and (4) the maximum amplitude over the anomaly.

Some of the data are rough estimates taken from data sets not originally intended for such analysis. Nonetheless, it was possible to obtain realistic values for the variables such that an exploratory analysis could be done. The results shown in Appendix M are summarized as follows:

1. The factor analysis isolated two factors that account for about 75% of the variance;
2. The communality summary indicates the variation in the individual variables that can be accounted for by the others is high (~80%). Combined they tend to improve the predicability;
3. The factors partition along duration and amplitude for one and frequency and area for the other. The variable of area loads on Factor 1, while duration loads at a similiar level on Factor 2;
4. Factor 1 is interpreted as related to debris signatures being more likely to reflect a pattern of low amplitude and short duration; and
5. Factor 2 is interpreted as more likely to reflect greater spatial frequency (e.g. peaks per unit area, which is more characteristic of historic shipwrecks than debris).

The use of statistical analysis of magnetic data is possible with this study's datasets and others generated outside of those typically obtained under NTL 75-3. This is due to the nature of those data versus those available from the cultural resources surveys conducted under NTL 75-3. This study's data was digitized and compiled for the specific types of statistical manipulation such as filtering, gradient removal, and spectral analyses carried out and reported herein. None of this has ever been done using data acquired under NTL 75-3. In most instances, the data exist only as raw strip chart records typically reported piecemeal and available only upon request by MMS technical reviewers. At this writing ony one company, ARCO, has experimented with digital data acquisition. Simple displays of such data allow easy anomaly recognition on adjacent lines (Figure 11-71) and the application of exploratory pattern recognition using multivariate techniques such as discussed here.

14.3 Summary and Conclusions

The Task II study analyses have been directed at the following objectives taken from the scope of services for this contract. They were:

1. Determine the relationship between survey linespacing and anomaly detection;
2. Determine the influence of oil and gas structures on magnetic anomaly distribution;
3. Characterize and differentiate, with a high degree of confidence, between modern ferromagnetic debris and potential cultural resources. This method must be applicable to present source material available to MMS cultural resource analysis.

The following is a summary of the results:

1. The detection of magnetic anomalies increases in direct proportion to the lane spacing used, e.g. the 150 m line interval detects one-third of the anomalies found using a 50 m line interval. This result may be specific to this particular study and the linear trend may differ with other data.

2. The developed lease block surveyed with oil and gas structures had the highest number of magnetic anomalies relative to the two undeveloped blocks surveyed. We conclude that development increases the number of anomalies of modern origin.

3. The present survey methodology is not developed enough to differentiate, at a high confidence level, between modern ferromagnetic debris and potential cultural resources. It represents a compromise between scientific and economic goals.

The present study has demonstrated methods by which one can more confidently characterize modern ferromagnetic debris and potential cultural resources. Pattern recognition has been demonstrated by using 50 m or less lane spacing by other state and federal agencies such as the Texas Antiquities Committee, the National Park Service, and the U.S. Army Corps of Engineers or by use of groundtruthing.

Recommendations to alter the present methodology have been made in past MMS sponsored studies notably CEI (1 977, Vol II) and SAI (1982, Vol 4) that still have merit. These include: conducting side-scan, magnetometer, and sub-bottom profiling surveys using 50 m linespacing in high shipwreck potential areas and limiting vessel speed to 2-3 m/s (4-6 knots). The recommendations in both Tasks I and II combine to reduce the general survey area on the OCS but increase the effectiveness of the surveys in lease block areas of reported shipwrecks with a high potential for their preservation,

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MMS 8$0023

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Reevaluation of Archaeological Resource Management Zone 1

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Minerals Management Service
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Prepared under MMS Contract
14-12-0001-30330
by
The Texas A&M Research Foundation
Box 3578
College Station, Texas 77843

Published by

U.S. **Department of the Interior**
Minerals Management Service
Gulf of Mexico OCS Regional Office

New Orleans
September 1989

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CITATION

Suggested citation:

Garrison, E.G., C.P. Giammona, F.J. Kelly, A.R. Tripp, and G.A. Wolff. *Historic shipwrecks and magnetic anomalies of the northern Gulf of mexico: reevaluation of archaeological resource management zone 1.* Volume I executive summary. OCS Study/MMS 89-0023. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, La. 3 Volumes, 6 pp.

ABSTRACT

As a result of Minerals Management Service (MMS) remote sensing surveys, numerous unidentified magnetic anomalies and side-scan sonar contacts which could represent historic shipwrecks have been recorded in the Gulf of Mexico (GOM). The objectives of this study are divided into two tasks. Task I provides a collection, evaluation, and synthesis of archaeological, environmental, and geographic data to evaluate and redefine the Cultural Resource Management Zone 1 (CRMZ1) in the Gulf. The CRMZ1 is an area considered to have a high probability for the occurrence of historic shipwrecks.

Task II was designed to establish an interpretive framework that would help identify the nature of magnetic anomalies and side-scan sonar contacts within the CRMZ1. Field studies were conducted to determine the relationship between linespacing of magnetometer and side-scan surveys and the percentage of objects detected on the seafloor. These data were then analyzed to investigate whether remote sensing data gathered during a cultural resource survey could discriminate between a cultural resource and recent debris.

The results from Task I indicate: (1) an increased distribution of shipwrecks in the eastern Gulf beyond the present CRMZ1 boundary but a low preservation potential at these wreck sites, and (2) a higher potential of finding shipwrecks around historic port areas in the central and western Gulf because of higher preservation potential.

Recommendations to relocate the CRMZ1 based upon both the distribution of reported shipwreck locations and their preservation potential are made. It is proposed that the CRMZ1 be moved to within 10 km of the Gulf coast and that specific higher probability zones be delineated outside the CRMZ1 that reflect the increased frequency of wrecks in the vicinity of ports and certain hazards.

The results of Task II indicate: (1) magnetic anomalies increase in direct proportion to area surveyed, i.e. the 150 m line interval detects one-third of the anomalies compared to a 50 m line interval survey, (2) survey areas with oil and gas structures have higher numbers of magnetic anomalies than undeveloped survey areas, and (3) the present survey methods used for cultural resource surveys are not sensitive enough to differentiate between modern debris and a potential cultural resource.

Other methods can more confidently differentiate between modern debris and shipwrecks. One method forms the basis of our recommendations on Task II which suggest using 50 m lane spacing for survey areas having a high potential for shipwrecks. The recommendations in both Task I and II combine to reduce the general survey area on the Outer Continental Shelf (OCS) but increase the effectiveness of the surveys in areas that have a high probability of both shipwreck density and preservation potential.

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ACKNOWLEDGEMENTS

The program manager and all of the principal investigators would like to acknowledge the assistance of the research assistants, secretaries, clerks, student technicians, student workers, laboratory technicians, draftpersons, and others who have been so instrumental in assembling this report for the Minerals Management Service.

The management staff on this project are involved in purchasing, report writing, and clerical duties which make it possible for the researchers to implement the procedures which are described in this report and their fine work is appreciated. The assistance of Mr. Mike Huddleson in coordinating project business with the Texas A&M Research Foundation, the Minerals Management Service, and outside vendors is most appreciated. Mr. William Crow coordinated many project logistics. The contribution of Ms. Susan Hulse in organizing, typing, and editing this report is most appreciated. The special help and extended efforts of Sherry Garvey, Andrea Hapeman, and Joanna Fritz are examples of how projects cannot be successful without the teamwork of wonderful staff. The work of the project field staff and the crew of the University research vessel, the R/V EXCELLENCE 11, is acknowledged. Their assistance in the implementation of field sampling procedures has been very valuable and is greatly appreciated.

Acknowledgement is given to student assistance Karen Trossel, Nancy Hitchcock, Susie Riley, Robert Lightfoot, Sherry Garvey, Kyle Baden, Karen Martin, and Diane Midge for their invaluable assistance in data analysis, compilation, and transmission. Eri Weinstein participated in the 1988 field surveys of lease blocks 313 and 332 as partial fulfillment of course requirements in his graduate studies. Mr. Ron Pierce gave his usual fine effort in locating materials and equipment necessary for the successful field studies. Mr. Ben Thigpen provided expert council on survey problems, drawing on exhaustive experience in the geophysical industry.

Several vendors and their representatives provided timely service and assistance. These include Mr. Terry S. Snyder (EG&G), Mr. John Fett (John D. Fett Instruments), Mr. Alistair Helme (Harvey-Lynch, Inc.), Mr. Larry Stephenson (Harry-Lynch, Inc.), Mr. Chuck Edgington (Del Norte Technology, Inc.), Mr. Andy Bogle (STARFIX), Mr. Jack Rhodes (STARFIX), Mr. Dick Smith (STARFiX), Mr. Jeff Raspberry (STARFIX), and particularly Mr. Max Huff (STARFIX). The tow-depth sensor used during the field studies was graciously provided by Teledyne Exploration, Inc. through the offices of Mr. Carl Bergland. EG&G Geometries gave its usual fine product support and is thanked for updating our G-866 magnetometer.

Our thanks go to Mr. James Baker and Mr. James Orr for preparing the excellent DISSPLA graphics included in this report. The staff of the Engineering Computer Services (ECS) of the Engineering Program, Texas A&M University, provided technical and advisory assistance over the course of the study. In particular, Mr. J. Robert Shaeffer (now with Boeing Computing Services), Mr. Jeff Cox (ECS) and the director of ECS, Dr. Donald Maxwell, are thanked. Dr. Maxwell authorized the acquisition of the NUMONICS digitizer and DEC 220/240 terminals so important to the manipulation and presentation of the large digital databases used in this study. The study benefited from his complete support as Interim Department Head, Civil Engineering Department, Texas A&M University,

Dr. Robert Bruner of the Geotechnical Area, Civil Engineering Department, erected the geodetic controls used in the resurvey of lease blocks GA 313 and GA 332. Dr. Bruner and his son, Bill, cheerfully rode boats and helicopters to erect the offshore positions to the highest degree of accuracy. The control points were erected on properties of Santa Fe Minerals and

Exploration Co., Lorac, a division of John E. Chance Associates, and the United States Coast Guard (Surfside, Texas). Each of these organizations is thanked for this courtesy.

We gratefully recognize ARMS, Inc. whose personnel, Mr. Nathan Gautheir (President), Mr. Randy Ducote, and Mr. Robert Simon were always able to accommodate our requests.

During the summer field studies several divers volunteered their assistance. Most were students of Texas A&M University and include: Mike Halpin, Marianne Franklin, Kenan Heideke, Alan Haubaker, Jim Hobling and Kathleen McLaughlin-Neyland.

Excellent examples of graphic displays of magnetic anomalies were provided by Mr. Robert Gearhart and Mr. Clell Bond of Espey-Huston and Associates, Inc., and by Mr. Rick Anuskiewicz. A photo of the machinery of the WILL O'THE WISP was generously loaned by Mr. Larry R. Martin.

Finally, we wish to thank those members of the Minerals Management Service we worked with most closely over the course of the study. They are: Dr. Norman Froomer, Ms. Melanie Stright, Dr. Richard Defenbaugh and Dr. Rick Anuskiewicz. Their counsel and assistance greatly enhanced the conduct and relults of this study.

EXECUTIVE SUMMARY

As a result of Minerals Management Service (MMS) required lease block remote sensing surveys, numerous unidentified magnetic anomalies and side-scan sonar contacts which could represent historic shipwrecks have been recorded in the Gulf of Mexico (GOM). These surveys also recorded numerous examples of relict landforms (fluvial channels, terraces, point bars, bays, lagoons, barrier islands, natural levee ridges, salt diapirs, and sinkholes) where there is a high probability for associated prehistoric sites.

Avoidance of further investigation of archaeologically sensitive areas is usually required prior to approval of lease permits; however, because industry has generally chosen avoidance rather than further investigation of these areas, little data have been collected which would help in building an interpretive framework for the evaluation of unidentified magnetic anomalies and side-scan sonar contacts, or in evaluating the predictive model for prehistoric site occurrence.

The objectives of this study are:

a. **To** reevaluate and make recommendations to change, if necessary, the location of Cultural Resource Management Zone 1 (CRMZ1) in the GOM (Figure 1).

b. To determine the relationship between linespacing of magnetometer readings and side-scan sonar and the detection of objects at or below the seafloor.

c. To investigate whether remote sensing data gathered during a cultural resource survey in the GOM can be analyzed to discriminate between a cultural resource and recent debris.

This study was divided into two major tasks: Task 1, Evaluation of Cultural Resource Management Zone 1; and Task 11, Establishing an interpretive framework to characterize unidentified magnetic anomalies and side-scan sonar contacts.

The data from primary and secondary materials collected at the various archives were merged and a master file of historic shipwrecks of the northern Gulf of Mexico was created. This file, with over 4,000 entries, represents the largest such data base for the Gulf.

Determining spatial patterns of shipwrecks in the Gulf of Mexico does not explain the causes for these patterns. These factors are not always independent. For example, increased frequency of shipwrecks along trade routes does not explain why the vessels were lost, only why they were there in the first place. Factors such as poor seamanship, poor navigation, scuttling, explosions, and fire cause shipwrecks.

An interesting **aspect of the analyses conducted on the data** in this study shows an increase in the number of losses over time. This contradicts conclusions **in** previous studies where the peak for shipwreck losses **was** expected to lie between 1880 and 1910. New data suggests that shipwreck loss continues to increase through the 20th century. This fact is somewhat surprising if one assumes that improvements in the technology of ship design, the use of diesel engines, and better navigational tools would reduce the number of ships lost over time. However, the rate of shipwrecks actually increases because of improved technology, Improved technology may allow more vessels to be exposed to risks that early mariners would avoid because of recognized shortcomings in their ships or navigational aids.

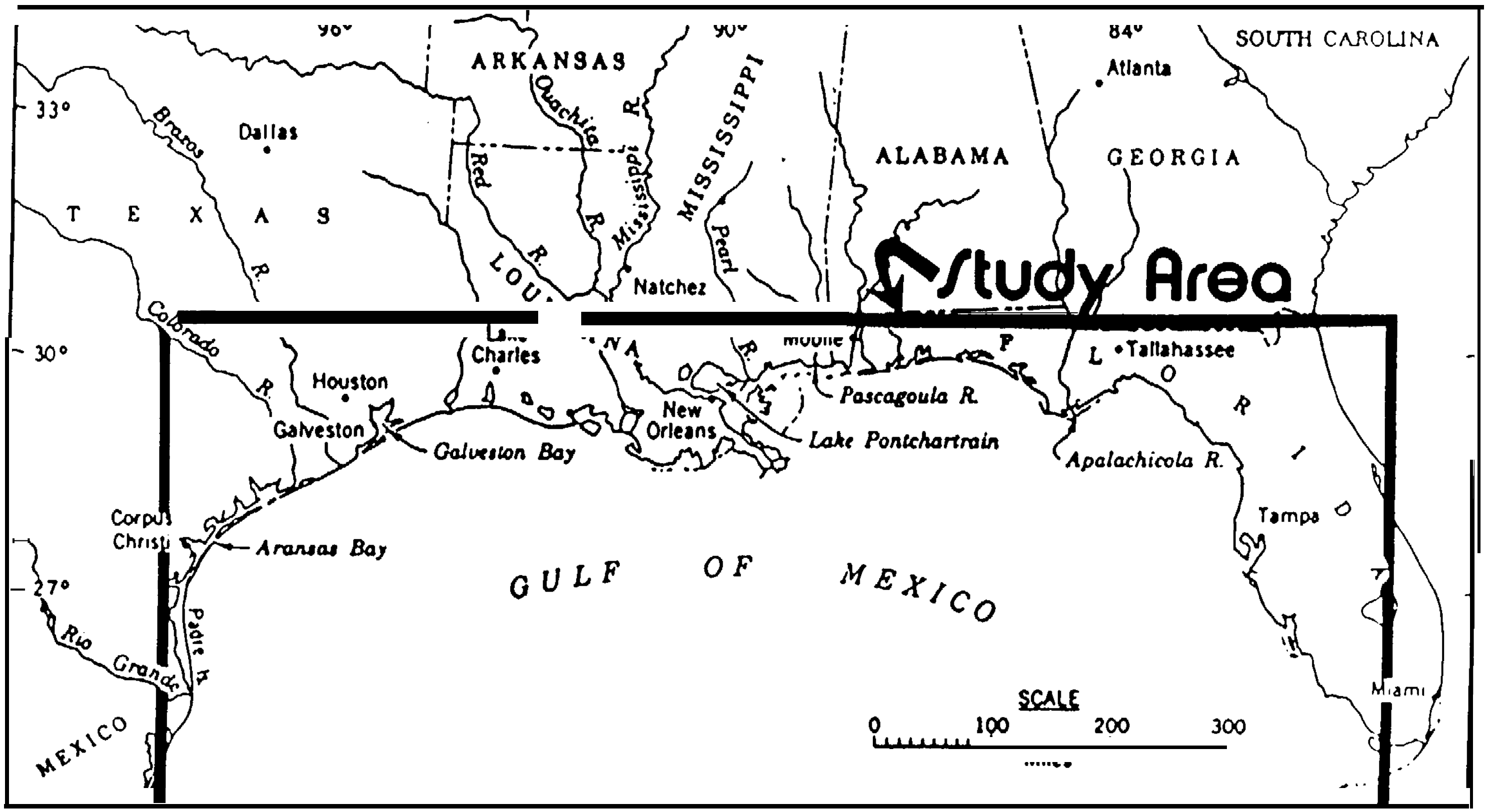

FIGURE I-1. Study area, CEI 1977.

The number of ships lost in the open sea versus those lost nearshore were discussed by Muckelroy[1], Bascom[2], CEI[3], and Marx[4]. Marx estimated that approximately 98 percent of all shipping losses in the western hemisphere prior to 1825 occurred in less than 10 m of water and within 1.5 km of the coast. CEI's authors followed this proposition when developing the CRMZ1. Muckelroy suggested that the 10 m boundary probably underestimated the potential for deep-water archaeology. Bascom concluded from a study of 19th century losses at Lloyds of London that about 20 percent of all sinkings occur away from the coast. This figure probably better approximates the correct order of magnitude for all sinkings in the open sea at any period. The data in this study support Bascom. An inspection of our shipwreck distribution plots shows that 75 percent of shipwrecks occur in nearshore waters and the remainder in the open sea. They conclude that wrecks are associated with the approaches to seaports, straits, shoals, reefs, and along the maritime routes. As we have seen in this study, the foregoing assumptions are largely supported by the data, but the authors deviate from their assumptions in the actual drawing of CRMZ1.

The potential for shipwreck site preservation is another important consideration in the overall analysis of the CRMZ1. If an area with a high potential for historic shipwrecks lacks the potential for preservation, that area may not need to be included within the boundary of the CRMZ1. An example of an area with negative environmental factors for site preservation is the region at the mouth of the Mississippi River. By historic accounts, it was an area of high ship concentration, The tremendous sediment deposits off the Mississippi Delta militate against finding a shipwreck in that area due to sediments of a depth that would insulate it from discovery.

Ships falling on areas of moderate to high sediment depths, hypoxic burial conditions, and low current regimes have good preservation potential. These conditions characterize much of the western and the west-central areas of the northern Gulf. It cannot be stated unequivocally that vessels sinking in sediment starved areas of the shelf, such as that of the eastern Gulf area, cannot be preserved, but based on results of this inquiry that probability seems low. In an area where burial or protection by fouling organisms exist, biofouling must be rapid in order to preserve vessel fabric or cargo. Until better data is available for the eastern Gulf, our expectation is that much of that area will be characterized by poor preservation of historic shipwrecks.

Records for shipwreck locations were merged with our assumptions concerning shipwreck preservation to derive a model for the potential of finding shipwrecks in the GOM.

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1 K. Muckelroy. 1977. <u>Maritime Archaeology</u>. Cambridge University Press. Cambridge.

2 W. Bascom. 1971. "Deep Water Archaeology." <u>Science</u>. 174(4006): p. 261-269.

3 Coastal Environments, Inc. 1977. "Cultural Resources Evaluation of the Northern Gulf of Mexico Continental Shelf." 3 Volumes. Baton Rouge, Louisiana. National Technical Information Services (NTIS) as: Vol. 1, Prehistoric Cultural Resource Potential, PB276773/AS; Vol. 11, Historic Cultural Resources, PB-276774/AS; and Vol. III, Maps, PB-286-874/AS.

4 Marx, R.F. 1971. <u>hipwrec sk of he estern Hemisphere. 149?-1 825</u>. David McKay Company, Inc., New York, NY.

The conclusions are derived from our present understanding of the shipwrecks in the northern Gulf of Mexico. Our study results indicate:

1. Increased distribution of shipwrecks in the eastern Gulf area beyond the present CRMZ1 boundary but a lower preservation potential relative to the central and western Gulf;

2. Previous underestimations of early shipwrecks in the central and eastern Gulf areas;

3. Increased potential of unreported shipwrecks in high density areas, e.g. a higher potential of finding wrecks in these zones because of higher preservation potential.

Recommendations for revisions of the CRMZ1 include:

1. Move the current CRMZ1 to within 10 km of the Gulf coast based upon the distribution of reported shipwreck locations and their probability of preservation.

2. Delineation of specific higher probability zones to reflect the increased frequency of shipwrecks in the vicinity of ports and certain hazards. They should have guidelines at least equal to those for the CRMZ1 and include:
   a Brazes Santiago-South Padre Island (TEXAS);
   b. Corpus Christi-Mustang Island (TEXAS);
   c. Freeport-Matagorda Island (TEXAS);
   d. Galveston-High Island (TEXAS);
   e. Sabine River (TEXAS);
   f. Calcasieu (LOUISIANA);
   g. Barataria Bay/Grande Isle (LOUISIANA);
   h. West Bay-Mississippi Delta (LOUISIANA);
   i. East Bay-Chandeleur Islands (LOUISIANA);
   j . Mississippi-Alabama Barrier Complex (Cat, Ship, Horn, Petit Bois, Dauphin Island)(MISSISSIPPI -ALABAMA);
   k. Pensacola-Santa Rosa Island (FLORIDA);
   1. Appalachicola-Cape San Bias (FLORIDA);
   m, Cedar Key (FLORIDA);
   n. Tampa-St. Petersburg (FLORIDA);
   o. Cape Sable (FLORIDA); and
   p. Dry Tortugas-Marquesas (FLORIDA).

3. Recognize individual blocks outside high probability zones and CRMZ1 proper according to the occurrence of specific historic shipwrecks. These blocks and immediately adjacent blocks should be considered as localized high probability areas such that surveys should consider the specific block and the eight contiguous blocks. Surveys conducted within these newly defined zones should utilize the survey methods recommended based on the results of the second part of this study.

Based on Task 1, we have indicated areas on the GOM OCS **that have high, moderate, and low probabilities** for the occurrence of historic shipwrecks. Task II of this study was designed to establish an interpretive framework to characterize unidentified magnetic anomalies and side-scan sonar contacts within the CRMZ1. It has the following two efforts: (1) Information collection; and (2) information analysis and synthesis. Two previously surveyed lease blocks (one that was not subsequently developed, and one that has been developed) were resurveyed for magnetometer and side-scan sonar data with survey linespacing at 50 m and navigation system accuracy at ±5 m. These data and the data from the original lease block survey were analyzed to determine the following:

1. The percentage of anomalies recorded during the survey at 50 and 100 m linespacings that was recorded during the original lease block survey at 150 m linespacing;

2. The correlation in anomaly locations, amplitude, duration, and signature (dipolar/monopolar) between the original and new surveys; and

3. The number of new magnetic anomalies and/or side-scan contacts that were recorded within the developed lease block, and the location of these anomalies relative to oil and gas structures.

Sites within lease blocks were selected for groundtruthing and signature characterization of unidentified magnetic anomalies and side-scan sonar contacts. Anomalies were chosen from the resurvey sites as discussed above. Groundtruthing and signature characterization included the following:

1. Relocating the anomaly or contact and collecting magnetometer and/or side-scan sonar data at a linespacing of 50 m or less;
2. Constructing a three-dimensional magnetic contour map of the unidentified magnetic anomalies, and magnetic anomalies with associated side-scan sonar contacts;
3. Identifying the source of the anomalous contact through diver inspection, using a hand held metal detector; and
4. Photographing any marine debris and historic shipwrecks where observable at the seafloor.

The results of the resurvey and groundtruth efforts include:

1. Post-plot maps that show the track of the survey vessel and navigational fix points at a 1:1200 scale and compare the findings of the original lease block survey with the resurvey data; and
2. Contour maps with a two gamma contour spacing of each magnetic anomaly that was investigated, and a catalogue of magnetic signatures for each object.
   (a) The survey and groundtruthing methods, and the instrumentation used is described and survey findings are discussed.
   (b) All the data collected during the field surveys were analyzed to determine the relationship between survey linespacing and anomaly detection, the influence of oil and gas structures on magnetic anomaly distribution and to characterize the changes at different distances and orientations to the magnetic sensors. The goal of the pattern recognition analysis of magnetic and side-scan sonar signatures is to develop a method that differentiates resources, and that can be used by MMS cultural resource analysts in the cultural resource survey review process.

The following is a summary of the results:

1. The detection of magnetic anomalies **increases in direct proportion to the** lanespacing used, e.g. the 150 m line interval detects one-third of the anomalies found using a 50 m line interval. This result may be specific to this particular study and the linear trend may differ with other data.

2. The survey of the developed lease block with oil and gas structures had the highest number of magnetic anomalies relative to the two undeveloped blocks surveyed. We conclude that development increases the number of anomalies of modern origin.

3. The present survey methodology is not developed enough to differentiate, at a high confidence level, between modern ferromagnetic debris and potential cultural resources. It represents a compromise between scientific and economic goals.

The present study demonstrates methods by which one can more confidently characterize modern ferromagnetic debris and potential cultural resources. Pattern recognition has been demonstrated by using 50 m or less lanespacing by other state and federal agencies such as the Texas Antiquities Committee, the National Park Service, and the U.S. Army Corps of Engineers or by use of groundtruthing.

Recommendations to alter the present methodology have been made in the past MMS sponsored studies notably CEI and SA15 that still have merit. These include: conducting side-scan, magnetometer, and sub-bottom profiling surveys using 50 m linespacing in high shipwreck potential areas and limiting vessel speed to 2-3 m/s (4-6 knots). The recommendations in both Tasks I and II combine to reduce the general survey area on the OCS but increase the effectiveness of the surveys in lease block areas of reported shipwrecks with a high potential for their preservation.

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[5] Science Applications, Inc. 1981. "A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West." 4 Volumes. McLean, VA.